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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LXXXVII.

EDITED BY

JAMES FORREST, Assoc. Inst. C.E., Secretary.

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SECT. III.—ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

CORRIGENDA.

Vol. lxxxv. p. 105, line 3 from bottom, *for* "0·3" *read* "0·03."
" lxxxvi. p. 322, line 18, *for* "110 parts of water" *read* "1,100 parts of water."
" " p. 343, lines 7 and 16 from bottom, *for* "Estcourt" *read* "Ladysmith."
" " p. 344, lines 32 and 33, *for* "clear-up" *read* "clean-up."
" lxxxvii. p. 150, line 19, *for* "28*s*." *read* "20*s*."
" " p. 305, line 6, *for* "them" *read* "it."
" " p. 306 (legend under the lower Fig.), instead of words "Haze-Brebner's" replace the hyphen with a full point.

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1886-87.—PART I.

SECT. I.—MINUTES OF PROCEEDINGS.

9 November, 1886.

EDWARD WOODS, President,
in the Chair.

Mr. WOODS, President, addressed the meeting in the following terms on assuming the Chair, for the first time, after his election:—

GENTLEMEN,—The honourable distinction which you have been pleased to confer, by electing me your President, demands my grateful acknowledgment, and I can only hope that my qualifications for performing the duties of so responsible and important an office, may be found in some small measure commensurate with my anxiety to promote and to sustain the interests of the Institution. I shall claim your kind indulgence for whatever may be my shortcomings in this respect.

The difficulty of selecting appropriate matter for my address, on the occasion of first occupying this Chair, arises not from the paucity of subjects which fall within the province of the engineer to consider, but from the fact that my distinguished predecessors in office have already dealt with many of paramount interest, whilst it would seem almost an act of presumption on my part to assume that other topics, to which I may now have to advert, will present any special feature of novelty, or perhaps even of interest to gentlemen whose attention has been specially directed to their consideration.

My connection with our profession dates from the time when I entered into the service of the Liverpool and Manchester Railway Company, so that it has been my good fortune to have had the opportunity of observing the gradual and progressive develop-

ment of the railway system. This circumstance may perhaps be accepted as my excuse for venturing to recall to your notice some of the steps by which this system of inland transport has attained the high position at which it has now arrived. Scarcely six months after the opening of that line for public traffic (which took place in September, 1830), the directors were enabled to report to their shareholders that "a new and extensive system of intercommunication, highly important to the interests of the mercantile community, and so extraordinary and complete in its character as to form an era in the progress of national improvements, and a striking epoch in the advance of mechanical science," had been inaugurated.

This statement has been, as we all know, abundantly verified in the course of the half century which succeeded the event in question. The vast capability of railways for the transport of merchandize as well as of passengers was then foreshadowed, and the assertion fortified by a reference to what was then considered an extraordinary performance, viz., that of "a new and powerful locomotive engine, the 'Samson,' made by Messrs. Robert Stephenson, which conveyed a load of 107 tons of merchandize from Liverpool to Manchester, at an average speed of 12 miles per hour, having been assisted in the ascent of the Rainhill incline plane (1½ mile of 1 in 90) by three other engines." The experiment, as the Report goes on to state, exhibiting "a practical answer to the confident, but ignorant assertion, that railways are not calculated for the conveyance of heavy goods."

It could hardly, however, then have been foreseen that within the next fifty years the railway and the locomotive would constitute the most important and nearly universal system of inland transport throughout the civilized world.

Until the opening of the Grand Junction Railway in 1837, and of the partial opening of the London and Birmingham Railway during the same year, and its completion in the autumn of 1838—undertakings commenced shortly after the success of the Liverpool and Manchester Railway had been established—no Great Trunk lines existed, and only a few short local lines, some of them being branches from, or dependencies of, the Liverpool and Manchester Railway.

Meantime engineers and deputations, from Canada, from the United States of America, from France and other continental States, flocked to England to study the working of the new system. Amongst these was Comte de Pambour, an officer of the French Government. He, with the permission of the directors

of the Liverpool and Manchester line, spent many weeks in investigating all the details of its working, and in recording the performances of its locomotives. The work which he afterwards published (in 1836), entitled "A practical treatise on Locomotive Engines upon Railways," was a valuable contribution towards the elucidation of the true theory of the application of steam as a motive power, and served to dispossess many of the accepted empirical rules which, being in the main founded on practice, in view of the special conditions under which steam had been theretofore applied, had no adequate scientific basis on which to rest the computation of the duty of the steam-engine under the new conditions imposed by the requirements of the locomotive-engine. The Liverpool and Manchester Railway, therefore, may be regarded as having afforded the pattern and example upon which (with such modifications as the experience of the first few years of its working had suggested) its immediate successors were designed and framed.

It may be of interest to recall a few of the principal steps of development which have led up to the state of efficiency which is now found to prevail, in regard both of road and rolling-stock.

The line from Liverpool to Manchester was originally laid on so-called fish-bellied rails of 35 lbs. per yard, resting in iron chairs, supported on stone blocks wherever solid ground permitted their use. Wooden sleepers were only adopted as a temporary measure where the road was on embankment, or on soft moss, and simply as affording ready means of lifting and adjustment until the bed had become well consolidated.

So much importance was at that time attached by the engineers to the provision of a firm and rigid foundation for the rails, that we find Mr. George Stephenson taking advantage of the rocky floor of the Olive Mount cutting, near Liverpool, to form a bed on which the chairs should directly rest. Again, Mr. Jesse Hartley, the Engineer to the Liverpool Docks, and possessing large experience and great faith in masonry constructions, when appointed Engineer of the Bolton and Manchester Railway, commenced, and carried out to a large extent, the system of building up, from the ground-level, solid stone walls on which he rested the rails. Mr. Brunel, preferring timber supports for the Great Western lines of rail, began by driving in piles to hold down the longitudinal half-balks of timber, on which he placed bridge rails.

All these methods were found, from one cause or another, to be defective; and, chiefly by reason of injury done to the rails through excessive rigidity, they had soon to be abandoned. It was

fortunate that, with the exception of the case of the Bolton and Manchester Railway, no great expense was incurred in acquiring the experience these trials afforded.

On the Liverpool line, the increasing weights of engines and speed of travelling soon necessitated a more substantial roadway, and led to the ultimate relaying, in successive portions, of the entire road, first with rails of 50 lbs., then of 62 lbs., afterwards of 72 lbs., and finally of the still heavier type now in use, made latterly of steel instead of iron.

The fish-bellied form was superseded at an early period by a rail of uniform section, an improvement resulting partly from the experience of a sample piece of the line so laid, and partly from the conclusions arrived at by Mr. Robert Stephenson in determining the form to be adopted for the London and Birmingham Railway, after an exhaustive inquiry, conducted by the late Professor Barlow, at the instance of the Board of Directors of that railway. Mr. Locke had elected to adopt a similar form of rail for the Grand Junction Railway, and to lay the entire line on wooden sleepers. Since then stone blocks have been abandoned, as it was seen that, although wood was of a perishable nature, its elasticity, and the facility which it afforded for repairs, materially diminished the cost of maintenance, and contributed greatly to relieve the rolling-stock from the shocks and jars it encountered in passing over a rigid road. The same considerations led to the general adoption of the compressed wooden key in preference to the iron key, for securing the rail to the chair. These variations, together with the subsequent application of fishing the joints of the rails, and the substitution of steel for iron, are embodied in, and constitute the accepted practice of, the present day.

Cast-iron sleepers have been used somewhat extensively on foreign lines, but it is not improbable that ere long steel sleepers may take the place of these as well as of wooden ones, and we already see such coming into use on several of our leading Trunk lines in England as well as on the Continent, whilst large quantities are exported to India, where, in addition to their other qualities, they afford exemption from the attacks and ravages of the white ant. The ingenuity of our mechanics is being successfully directed to the devising of simple and effective means of securing the rails to such sleepers.

Generally the substitution of steel for iron rails has been attended with most beneficial results to all railway companies, a change which was rendered possible by the inventions of Sir Henry Bessemer, and of the late Sir William Siemens, and by the keen

competition of manufacturers, enabling supplies of this material to be obtainable at less than one-half the price which iron rails commanded not many years ago. Within a recent period contracts have been made for steel rails of heavy double-headed section delivered free on board at less than £3 10*s*. per ton; whilst in 1870 the market prices of iron rails of similar type ranged as high as £7 10*s*. per ton, steel rails then ruling at £10 per ton. The original rails of the Liverpool and Manchester Railway were, as far as my recollection serves, delivered at the price of about £11 to £12 per ton (1829).

On the main lines of this country steel rails weighing from 86 lbs. to 90 lbs. per yard are now coming generally into use, lighter rails being no longer adapted to sustain the heavy weights which in our modern and powerful locomotives are concentrated on a single pair of wheels, a weight in some cases amounting to 17½ tons. In other cases, where it is permissible to couple two or more pairs of wheels and distribute the weight of the engine over a larger number of them, lighter rails can be, and are, used with advantage. In this way rails varying from 42 lbs. to 65 lbs. per yard are employed very extensively on the lines of the American Continent and elsewhere.

The question of gauge elicited scarcely any discussion in the case of the Liverpool and Manchester Railway. The gauge of 4 feet 8½ inches was adopted without hesitation as a convenient one, being identical with, or closely approximating to, the gauge of the Stockton and Darlington line. It was in 1838 that the question assumed importance, and the battle of the gauges raged fiercely in consequence of the adoption, by Mr. Brunel, of 7 feet as the gauge of the Great Western and its tributary lines.

Whatever may have been the mechanical advantages due to such increase of gauge, these, as time passed on, were shown, as regards English railways, to be far outweighed by commercial considerations incidental to the obstructions arising from break of gauge, and to the consequent diversion of traffic to the lines of other companies. These motives eventually determined the Great Western Railway Company to adopt the mixed (broad and narrow) gauge over nearly all portions of that system, which theretofore had been laid on the broad gauge.

The history of the events which led up to conviction that steam-power was destined to become the chief agent for land transport in the immediate future is too familiar with all to bear repetition; but it may not be out of place to observe that even the most advanced

type of locomotives of the present day retains the essential characteristics of that which held the field at the commencement of the era to which I have referred. The important features common to both included the water-surrounded furnace chamber—the multitubular boiler—the wheels mounted either on crank or on straight axles, whether single or coupled, driven by a pair of horizontal or inclined cylinders, the smoke-box and the steam-blast to intensify the draught.

As time went on, great improvements, it is true, have been effected in most, if not in all, constructive details, whilst the progressive increase of traffic required a corresponding augmentation of the power necessary to haul the trains. Hence we find that locomotives of the present day possess, as a rule, at least four times more steaming power coupled with six-fold weight than those of the class represented by Messrs. Robert Stephenson and Co.'s engine, the "Planet," the approved type of the period from 1832 to 1836. The "Rocket" class had before this proved too deficient in power for conveying the regular traffic.

Contrasting the two types, we see that the approximate comparison as regards weight is as 7½ tons to 45 tons; as to firegrate area, as 7 square feet to 20 square feet; and as to heating surface, as 300 square feet to 1,400 square feet.

The successive changes and improvements from time to time effected have not only served to enable our traffic-managers to cope with the ever-increasing volume of traffic, but have also been the means of procuring great economies in the conduct of it. I may refer to a few out of the many instances in which a marked and enduring influence has been exercised.

In the article of fuel a great saving was effected on the Liverpool and Manchester Railway by an improvement in construction of the slide-valves. This, by permitting the free discharge of steam after its work in the cylinders had been done, relieved the engines of a resistance which theretofore had absorbed and neutralized a large portion of their power. The alteration throughout the stock could only be carried out gradually as the engines came in for repairs, or as new engines could be built in the company's workshops to gradually replace such as did not admit of alteration. The result, in great measure attributable to the change in question, was that whereas 12,600 tons of coke were consumed in the service of the traffic in the year 1839, only 3,100 tons, or one-fourth that quantity served four years later, viz., in 1843 for the conduct of a traffic of greater volume, the diminution in the meantime being steadily progressive from year to year.

The application of expansive working by mechanism actuating the slide-valve, coupled with the use of steam at higher pressures, was initiated as regards the locomotive by the late Mr. John Gray, in the year 1838, and first fitted by him to an engine called the "Cyclops."

This somewhat complicated and cumbrous apparatus was afterwards superseded by the "link-motion," a simple and beautiful piece of mechanism, which, as is well known, has been brought into almost universal use. It was the invention of Mr. William Howe, an intelligent mechanic in the employ of Messrs. Robert Stephenson and Co., of Newcastle, and was adopted for the first time in their works in August, 1842. The idea appears to have been suggested simply with the object of easier reversing the direction, an improvement on the older arrangement of the "double gab," under which the forked or "gab" ends of the two eccentric rods, actuated by their respective eccentrics, were connected by a short link, and thus lifted or lowered simultaneously the one into, the other out of, gear, according as it might be required to drive the engine forwards or backwards. This motion involved the stoppage and sudden starting again of the slide-valve whenever the operation had to be performed, an operation attended with considerable shock and risk of derangement or fracture when performed whilst the engine was in rapid motion. For the simple link, Howe substituted a slotted one, with a block sliding in it, carrying a pin to actuate the valve-rod, and adjustable within any given position within the link by the lever under control of the driver, so as to impart to the valve, without arresting its action, the special motions necessary for reversing and cutting off steam. This invention, if it had been patented, would doubtless have proved a most lucrative one; but the inventor did not possess the means to secure the patent right, nor does it appear that its prospective value was, in the first instance, duly and fully appreciated by him. Combined with the high pressures of steam now used, 140 to 180 lbs. per square inch, the link-motion has contributed greatly to economising of fuel in the locomotive.

Certain substitutes for the control of valve-motion by the link gear have been in some cases, and with advantage, adopted both in locomotive- and marine-engines. They possess the merit of simplification of parts, and of greater accuracy in regulating the points of cutting off and of releasing the steam. Amongst these the most typical and effective is the invention of Mr. Joy, patented some eight or nine years since. Eccentrics are dispensed with,

and the movement of the valve is produced by a combination of two motions at right-angles to each other, taken direct from the connecting-rod and giving both the reversal of motion and the various degrees of expansion required without interruption of the continuity of motion in the valve. For this form of valve-gear are claimed accuracy of result, reduction of cost, saving of room which can be advantageously applied for introducing larger cylinders, obtaining thereby a higher rate of expansion, and increasing the area of wearing surfaces for all the main bearings. Express engines on the London and North-Western, Great Eastern, North Eastern and other lines, have been fitted with this gear. I am informed that the number of locomotives thus provided now amounts to about five hundred. Valve-gear of a somewhat analogous kind has been used on the American Continent and also in some European countries—the inventions, one of Mr. Stevens, the other of Mr. Walschaert.

On most if not on all the leading passenger lines of this kingdom, coke was the fuel used in the furnace of the locomotive-boiler up to the year 1852, owing to its freedom from smoke; but its greater cost as compared with coal led to the consideration of methods by which the combustion of this last-named fuel might be effected without the production of an objectionable amount of smoke.

Increased area of firegrate permitting a slower rate of combustion, a larger capacity of furnace, with appliances therein for maintaining high temperature of the evolved gases and for effecting the admission and directing the current of saturating volumes of atmospheric air, sufficed to solve the problem, and thus to secure the vast savings which have been accomplished as due to the difference of cost of the two descriptions of fuel.

The contrast in point of efficiency between the locomotives of the present period and those of half a century ago is sufficiently striking, and it may not be out of place to mention certain characteristic particulars kindly furnished to me by the engineers of several of the leading lines of railway in this country and in North America, illustrative of the most approved types which are now employed in the conduct of the express passenger and heavy merchandize and mineral traffic of their respective lines.

A rough average derived from the corresponding engines of those respective types as in use on the London and North-Western, the Midland, the Great Northern, the Great Western, the North Eastern, the London and Brighton, the Caledonian, and the Lancashire and Yorkshire Railways, presents the figures

given in the subjoined note, as fairly representative of modern practice.[1]

The relation as regards weight and power which these engines bear to those of the early period referred to may be thus expressed. As to tractive power the increase is at least five-fold, having regard to the proportions of the parts, the steaming capacity of the boilers, and the higher pressures of steam at which the engines are now worked.

Amongst the locomotives above-mentioned are some in which the system of "compounding" now engaging the serious attention of our mechanical engineers, has been successfully carried out. I note in particular the three-cylinder express passenger engines of Mr. Webb, running on the London and North-Western Railway, and the two-cylinder engines of Mr. Worsdell, introduced by him on the Great Eastern and recently on the North Eastern Railway, in respect of which a considerable saving of fuel is claimed (and I believe justly) to have been effected, amounting to some 5 lbs. per train-mile, or about 20 per cent. on the consumption of ordinary engines. Success on these and other lines, once established, will doubtless lead to the more general adoption of that system, both for passenger and goods traffic.

Inclines which at one time were regarded as too formidable to be worked advantageously by locomotives, are readily sur-

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[1] *Express Passenger Engines.*

Weight of engine in working order, say . . .	42 tons.
Greatest weight on a single axle	15 „
Area of firegrate	19 square feet.
Heating-surface	1,300 „
Pressure of steam in boiler	140 lbs. per sq. inch.
Tractive power, assuming an average effective pressure of steam in the cylinders of 90 lbs., per square inch	8,900 lbs.

Merchandize or Mineral Engines not being Tank Engines.

Weight in working order	38¼ tons.
Greatest weight on an axle (N.B. axles coupled)	14 „
Area of firegrate	18 square feet.
Heating-surface	1,300 „
Pressure of steam in boiler	140 lbs. per sq. inch.
Tractive power, assuming on an average effective pressure of steam in the cylinders of 90 lbs., per square inch	12,690 lbs.

mounted by the powerful engines of the present day. Hence we find gradients of 1 in 50 and 1 in 60 common on many railways, whilst important lines, ascending and crossing mountain ranges in different parts of the world, have continuous ascents of many miles in length of 1 in 25, 1 in 30, 1 in 33, &c., worked by engines differing only from such as are common in England in the circumstance of greater dimensions and capacity, and adjusted so that the weight on the coupled wheels shall be sufficient for the utilization of the tractive force they are designed to put forth.

The great length of many of the American and Canadian railways, the heavy gradients occurring in the crossing of mountain ranges and the limitation of the number of trips with a view to economy, are conditions which have led to the adoption of a class of locomotives capable of conveying immense loads, and of coping with the mountain slopes of those regions.

There are many types of these locomotives, but the "Consolidation" engine (so called from its being designed at a time when several railways were being united) appears to be the favourite engine in the United States for work on long grades. Those on the Northern Pacific Railroad have a grate-area of 30 square feet and a heating-surface of 2,000 square feet, with four pairs of coupled driving-wheels 4 feet 1 inch in diameter, and a four-wheeled bogie truck in front, the weight on the four driving-axles being 45 tons, and that on the truck 6¼ tons. These were built at the old-established works of the Baldwin Company, by whom I have been kindly supplied, through Mr. Barnett, the Locomotive-Superintendent of the Grand Trunk Railway of Canada, and President of the American Railway Master Mechanics' Association, with the sizes and sketches of six different designs of "Consolidation" engines, and amongst them that of a most powerful engine for working mountain grades of 316 feet per mile (1 in 17) employed for provisionally working a temporary "switch-back" track or zigzag 15 miles in length, crossing the Raton Range of the Rocky Mountains on the New Mexico and Southern Pacific Extension of the Atchison, Topeka and Santa Fé Railroad. It is an eight-coupled engine with two-wheeled "Pony truck" in front, with a weight of 45 tons on the driving-wheels and a total weight of 50 tons; the cylinders are 20 inches by 26 inches; the wheels 42 inches in diameter; the tractive power 247 lbs. per 1 lb. pressure of steam per square inch on the piston; the area of firegrate is 27½ square feet, and the heating-surface 1,376 square feet.

The following performances are reported:—

It hauled, exclusive of the engine and tender,

On gradients of	1 in 50 = 482 tons gross	at	8 miles per hour.
„	1 „ 29 = 258	„	8	„
„	1 „ 17 = 194	„	6	„

These performances must have involved a tractive force exerted of at least from 26,000 lbs. to 33,000 lbs., corresponding with an effective average pressure on the pistons of 106 lbs. to 134 lbs. per square inch. So high a result could only have been obtainable under favourable circumstances of weather, allowing a maximum of adhesion between wheel and rail.

Another type of locomotive, built by the "Strong Locomotive Engineering Company" of Philadelphia, is specially adapted for burning anthracite and inferior kinds of coal. To effect this object the grate of the express and freight locomotives attains an area of no less than 62 square feet, or more than double that of the "Consolidation" engine above mentioned, the rate of combustion being thereby reduced by 50 per cent., admitting the use of a very thin fire. The furnace and combustion-chambers are corrugated cylinders, their ends are dome-shaped, and thus staying is dispensed with. Their form and construction differs materially from those of the ordinary firebox. The valve-gear is of special construction, worked from a pin in the connecting-rod through the medium of links and levers, cutting off from 3 to 20 inches without affecting the exhaust.

From a very early date the application of the four-wheel bogie truck,[1] or of the two-wheeled (so-called) "Pony" truck, came to be very general on the lines in the United States, affording great flexibility both laterally and vertically, and therefore specially adapted to traversing the sharp curves and compensating the irregularities of track, which at that time subsisted in the rapidly and economically constructed railways of the period. The advantages accruing from the adoption of this mode of support to the leading, and sometimes also to the trailing end of the locomotive, have led to its extensive application in later times on roads of a more substantial description, both on the American Continent, in our own islands, and in some parts of Europe.

By locomotives partaking of the character of those above referred to, whether of similar or somewhat varied dimensions, and as subject to the special circumstances of each case, gradients, thought impossible to be worked by locomotives dependent on

[1] An account of the invention of the bogie truck is given in the "Railroad Gazette" (New York), Nov. 26, 1886.

adhesion of their coupled wheels by simple contact with the rails, are now constantly and readily surmounted.

Amongst the steep inclines of important railways so worked the following may be enumerated as typical. The Lima and Oroya Railway crossing the chain of the Andes, with a summit-level of 15,672 feet above the sea, attained in a distance of 100 miles by gradients of 1 in 25, and 1 in 34. The Arequipa and Puno Railway, also crossing the Andes, at a summit-level of 14,666 feet above the sea, with maximum gradients of 1 in 25. The Denver and Rio Grande Railway crosses the mountain range at a summit-level of 10,850 feet above the sea, with ruling gradients of 1 in 30. The Union Pacific Railway, crossing the range of the Rocky Mountains at a summit-level of 8,242 feet, with ruling gradients of 1 in 88. The Mont Cenis and the St. Gothard Railways, piercing the Alps at elevations of 4,246 and 4,379 feet, with ruling gradients of 1 in 33 in the case of the former line, and 1 in 40 and 1 in 38 in that of the latter. The Brenner and the Sömmering Railway have ruling gradients of 1 in 40 to 1 in 43. The railway over the Blue Mountains (Australia) attains the summit by an almost continuous gradient of 1 in 30 to 1 in 33.

The limit of inclination admitting of being surmounted by locomotives of these types appears to be practically reached at about 264 feet to the mile (1 in 20), for beyond that limit the weight necessary to be given to the engine to procure adhesion absorbs, by reason of the gravity of its own mass, the greater part of the power it is competent to exert. Resort must then be had either to the stationary engine and rope, or to one or other of the systems which have within a recent period been reintroduced.

Pending the completion of the tunnel between Modane and Bardonnèche, the system of pressure contact between wheels and rails was exemplified in 1867 with considerable success in the Fell Railway laid over the Mont Cenis, with maximum gradients of 1 in 12. The traffic across was thus carried on for many months. As adhesion varies between smooth surfaces with the state of the rails, it was seen to be important in such cases to adopt a system which should render the contact independent of the state of the weather, and the attention of engineers in seeking to solve the problem naturally reverted to the idea of the rack-and-pinion arrangement, which was patented by Blenkinsop in 1811, and applied on one or more colliery tramways in Yorkshire.

The Swiss engineer Mr. Riggenbach, of the Swiss Central Railway, constructed the first mountain railway in Europe, from Vitznau on Lake Lucerne to the Rigi Kulm, which was com-

pleted in 1871. Its maximum gradient is 1 in 4. A road of similar construction, viz., with centre rack-rail, into which the pinion on an axle driven by the locomotive geared, had been completed in 1869 by an American engineer, Mr. Sylvester Marsh, leading to the top of Mount Washington, its maximum gradient being about 1 in 3.

Whereas Blenkinsop's rack-rail had been made of cast-iron, with teeth of the usual form, the rack-rails of the two mountain roads were made of wrought-iron, ladder fashion, the sides of angle-iron, and the rounds riveted in to serve as cogs. They have worked the tourist traffic successfully, and with considerable profit, ever since.

More recently Mr. Abt, the Constructing Engineer associated with Mr. Riggenbach, has introduced a new rack-system, substituting for the ladder rack a rack-rail, built up of two or more elementary racks placed side by side, with broken joints and teeth ranged in steps, giving continued contact, and consequently smoother motion. The driving-pinion is composed of as many toothed disks as correspond with the greatest number of elementary rack-bars laid down on any given section at the road. The number of such bars is adjusted in relation to the gradients, so that each bar shall be subject to not more than a specified limit of strain, so as to come within the factor of safety.

Mr. Abt has constructed a line in the Harz Mountains, in which this principle has been adopted. It is about 16 miles in length, of which a length of 3½ miles is furnished with the rack-rail. The locomotives, weighing 54 tons gross, with 42 tons on the adhesion-drivers, are arranged to work in the ordinary way on the lighter gradients, *i.e.*, up to 1 in 40, the pinion and rack being put into gear when the steep inclines are to be surmounted. These latter range from 1 in 16 to 1 in 22. The success of this system, as evidenced by the work now being done on this line, augurs well for its more extensive application to districts in which the conditions are similar, and may serve to bring into profitable commercial connection places which otherwise, and without very costly works, would remain isolated.

Our notions with regard to gradients have certainly undergone an important change during the last forty years. There existed, and still exist, two inclines (each about 1½ mile in length) of 1 in 90 on the main line of the Liverpool and Manchester Railway, which from the first have been worked by locomotives; yet these were considered of such an exceptional character, that Mr. George Stephenson had originally contemplated and provided for the

erection of fixed engines, at their respective summits, for working the ascending traffic by ropes.

It was considered a bold and even hazardous undertaking, on the part of Mr. Locke, to carry the line of the Lancaster and Carlisle Railway up the slopes of Shap Fell for 7 miles, on a gradient of 1 in 70, to be worked by locomotive power. Indeed Mr. Robert Stephenson had, in the case of the London and Birmingham Railway, fixed the limiting gradient at 16 feet to the mile (1 in 330). No doubt these engineers exercised a sound judgment in the instances I have mentioned, their decisions being arrived at from considerations determined by prescribed conditions and comparison of advantages and disadvantages due to lessening the cost of transport on the one hand, and increasing capital outlay on the other.

Concurrently with the increase of traffic, the increased speed at which it had to be conducted, and the increased number of trains that it was necessary to provide for daily, fresh agencies were brought to bear, without the aid of which those conditions and requirements could not have been satisfied.

To the present generation it would seem difficult to realise that for many years after the inauguration of the railway system the use of distant signals was unknown; that to stop a train, the gateman or signalman had to wave a flag or a lantern, or to mount a ladder at his lamp-post, take out the lamp from its iron, and replace it with its red bull's-eye turned towards the advancing train. After this came the introduction of lamps, mounted permanently on lamp-posts, and operated by a lever from below; and more recently the introduction of the "distance-signal," and the appliances necessary for controlling it from the home signalman's station.

Still later did it become possible to actuate all the switches opening into the sidings and cross-roads of a station from a central signal-box, supplemented afterwards by the admirable arrangements for interlocking, and the simultaneous control of signals as depending on the altered positions of those switches, the mechanism contrived for the accomplishment of these objects being brought to a high state of perfection by the inventions of Messrs. Saxby and Farmer, Messrs. Stevens, and others.

Then we had the invention of the electric telegraph, effecting instant communication between station and station, and afterwards the establishment of the "block system," which, when carried out properly, would seem to have reduced the chances of collision to a minimum, so far as signalling is concerned.

As the power of the engines was increased, so also was the time

of getting up speed after stoppages diminished, enabling the speed on a long journey to be maintained at a higher average, whilst the average in the case of passenger trains was further augmented by the application, now very general, of the continuous brake.

This apparatus was introduced at a comparatively recent date, for up to the year 1874 the use of the ordinary hand-brake, as applied to the tender and to a couple of vans, or even to a single van, prevailed on our leading lines of railway, with the exception of the Lancashire and Yorkshire and the East Lancashire Railways. It was in 1858, and consequent upon the reports of their inspecting officers, that the Board of Trade had, by a circular of their then Secretary, Captain Douglas Galton, called the special attention of the railway companies to the fact that the amount of brake-power then habitually supplied was insufficient to prevent the frequent occurrence of accidents from collisions, many of which they considered might have been modified or averted had the trains been more adequately supplied with brake-power. Special reference was made to the two systems, those of Newall and of Fay, which had come into daily use on the above-mentioned railways.

By the trials of different systems of applying brake-power, conducted on the line between Lincoln and Nottingham in 1875, under direction of a Royal Commission, it was shown that whereas by the application of hand-brakes, applied as they then habitually were, a train of 200 tons gross weight, going at 50 miles an hour on a level line, could only be brought to a stand within a space of about 1,490 yards; a similar train of the same weight, travelling at the same speed, but provided with a suitable description of continuous brake, could be brought up in eighteen seconds, from the time of applying the brake, within a space of only 300 yards.

The advantage resulting was so obvious, and the urgency so great, that most of the companies saw it to be to their interest to apply some form or other of continuous brake to their passenger rolling-stock, notwithstanding the heavy cost which it entailed. This general recognition of its value may therefore be regarded as dating from 1875.

Meantime the comfort of the travelling public had not been neglected, and it has been largely supplemented by the improvements which have been effected in rolling-stock.

The model at first followed in the construction of passenger-carriages was based substantially on the adaptation of the type of the old six-inside passenger stage-coach, and the four-inside mail-coach to the new development. The compartments of the first railway-carriages were only slightly more capacious. Each train

carrying a mail was provided with a carriage of the orthodox mail-coach colour, attached to the rear, with two compartments containing four passengers each, and a *coupé* for two, and at the back the elevated outside seat of the mail guard, with his "Imperial" for the mail-bags mounted on the roof. In lieu of this we have now the well-appointed separate mail-van, thoroughly lighted, provided with accommodation for clerks and for the sorting of letters, and for the passengers luxurious carriages of different descriptions, some of them fitted up with all accessories necessary for sleeping and dining on the road. Second-class passengers, who are now conveyed in comfortably cushioned carriages, protected from the weather, were then thought to be sufficiently accommodated in carriages, or rather trucks, the sides of which were only a little higher than the seats, with a roof, it is true, overhead, but with the sides open and exposed to wind and rain, such, however, affording them better protection and greater comfort than could be obtained when travelling on the outside of the old mail coach.

Although it does not fall within the scope of the present address to consider the progress made of late years in foreign countries, otherwise than as bearing directly upon our own railway industries, I may perhaps venture to refer to some engineering works carried out in the North of Spain, which, largely by the application of British capital, have not only been attended with important results as effecting economy in the construction and working of railways, but have at the same time subserved the industrial interests generally of this country. I refer to the great change which has taken place consequent upon the substitution of steel for iron in the manufacture of rails, and of various structures which heretofore have been made of iron. The mines in the North of England proved inadequate for the supply of hematite ore, at moderate price, in quantities commensurate with the rapidly increasing demand for steel. Hence, in 1871, the attention of ironmasters in this country was anxiously directed to the procuring of adequate supplies of such ore.

The district around Bilbao, and specially the mountains of Triano, in the neighbourhood of Somorrostro, had from time immemorial been known for the abundance of its iron ore. The ancient workers, the Romans and the Moors, had driven galleries into the lodes cropping out from the hillsides, and, following up the soft veins of ore, had been able to reduce with ease, in their so-called Catalan forges, an iron celebrated for its ductility,

its freedom from sulphur and phosphorus, and its otherwise superior quality. This, then, was seen by our English manufacturers to be a suitable field from which to derive additional supplies. They took measures for having it thoroughly investigated and reported upon.

Of the several mineral lines established by foreign capital for bringing down the ore to the port, the first and longest (22 kilometres in length), now called the Bilbao River and Cantabrian Railway, was constructed under my direction by a company promoted by iron-masters in Sheffield. It skirts the mountains of Triano, and has for its terminus at one end the mines of Galdames, and at the other a point of the estuary not far from the mouth of the River Nervion. The works were commenced in 1872, and completed in 1875, after serious delay and interruptions caused by the Carlist War. The district through which the line passes had been in the meantime the seat of the most terrible struggles of the war.

Owing to these and other difficulties arising out of the situation, the first shipment of mineral transported over this line took place early in May 1876. Previous to this date the first enterprise of the kind in Bilbao, the mines of Triano, more generally known as those of Somorrostro, had alone been served by a line which had been in existence since 1865, without contributing very largely to their development. It was constructed, and has throughout been worked by the Provincial Deputation, an administrative body for the management of the affairs of the province. Starting from the river at San Nicolas (El Desierto), it terminated in a valley at the base of the Triano Hill, the ore being brought down to the terminus in bullock-carts, and there loaded into the railway-trucks. This mode of communication has been since, however, supplemented by a wire ropeway.

The opening of the Galdames line (Bilbao River and Cantabrian Railway) was followed in 1877 by that of the Orconera line, giving access to the very valuable mines of Matamoras, with a branch into the Triano mines, and still more recently by that of the Franco-Belge Company in 1880. The whole district is now intersected with a network of branches supplementary to the main lines of railway, and consisting of light tramways, self-acting inclines, and overhead wire ropeways.

The exportation of iron ore from the Bilbao River during the ten years previous to 1870, had risen gradually from 54,000 to 246,000 tons per annum, a nearly 35-per cent. rate of increase in

that period, but still greatly below that which it afterwards attained.

A great hindrance to the rapid development of the trade of the port had consisted in the limit imposed on the size of ships trading thereto, by reason of the deficient depth of water on the bar. The bar was a shifting one, its position changing from time to time by the variations in the direction of the wind, and the force and volume of the outflowing land-waters. Vessels of 12 feet draught, carrying 900 tons, could only leave at the top of the tide, and vessels of larger draught and capacity were constantly being detained until spring-tides afforded the necessary depth of water.

About the year 1861 the late Mr. Charles Blacker Vignoles, Past-President Inst. C.E., who was Engineer of the railway from Bilbao to Miranda, made a survey of the port, and submitted a comprehensive design, consisting in the main of a breakwater outside the bar, connecting the opposite shores of the bay with a suitable entrance for ships. Means were not forthcoming to defray the cost of the proposed works, and no action was taken in respect to them.

The time having arrived for the matter of port improvements to be seriously taken up, the representatives of the principal interests concerned associated themselves with the Bilbao Chamber of Commerce in engaging Sir John Coode, to examine the question and advise on the construction of such works (designed on a more limited scale than those of Mr. Vignoles), as might serve to increase the depth of water on the bar, and improve the river generally for the accommodation of a possible export traffic of from 2,500,000 to 3,000,000 tons of ore per annum.

Sir John Coode made his report in 1873, and having regard to the circumstance "that the bay was totally unprotected from the north-west," and "to the limited normal depth of water over the bar," he recommended the following works:—A breakwater across the bay, with a central portion 3,000 feet in length, and two arms of 800 feet each. Guiding works to direct the currents passing in and out across the bar. Dredging of the river channel near its mouth to a depth of 16 feet 6 inches at low-water of spring-tides, and diversion of the channel in two places. The cost of the whole was estimated at £1,100,000, and the time for completion about eight years.

There is no doubt that this project, if it could have been then carried into effect, would have afforded an admirable solution of the problem; but, unfortunately, the resources of the local authorities were not found adequate to the outlay involved, and matters

remained in abeyance for a period of four years, during which the delays sustained by ships, detained from want of sufficient depth of water over the bar, and the consequent limitation of the amount of exports, aroused the authorities to the necessity of making a vigorous effort to reduce, and if possible to remove, the evil.

Accordingly, with the sanction of the Supreme Government, a Board of Works was constituted for the improvement of the river, with power to levy a tax on imports and exports, to be applied to covering the requisite outlay. The services of Mr. Evaresto Churruca, a Spanish Government Engineer, were engaged by the Board, and certain works designed and recommended by him after careful study of the various projects of improvements which had from time to time been submitted, including those of the English engineers, were sanctioned by the authorities at Madrid. These works were promptly initiated, are now partially executed, and it is expected will be completed by the summer of 1888.

The principal objects kept in view were the opening of the river at high-water at all times to all the vessels trading with the port, entrance being then practicable only during spring-tides, the admission of vessels of greater draught by increasing the depth of water on the bar; the improvement of the conditions of the river generally by means of training-walls and by dredging; the prolongation of the western mole at Portugalete, at the mouth of the river, to a point beyond the banks of the bar so as to fix the direction of the channel, and intensify the scouring-action of the tidal and freshwater currents.

These ends have been steadily pursued with the result that, although some of the works contemplated have not yet been finished, the improvements already effected are of a most marked and important character. Mr. Churruca's report for 1885 states that vessels now leave the river with 17 feet draught at neap-tides, whereas formerly they could not venture on more than 15 feet on the highest of spring-tides. In October, 1884, the steamer "Rivas" sailed with 21 feet of draught laden with 3,340 tons of ore, and 130 tons of bunker coal (in all 3,470 tons), while four years earlier the largest cargoes did not exceed 1,500 tons. In the same report Mr. Churruca remarks, "The entrance to the river, although it has much improved, is far from exempt from risks when there is a heavy sea, and to overcome these it would be necessary to construct outside sheltering-works which are beyond the limits at the Board's disposal." Such sheltering-works in the shape of breakwaters were essential features of Sir John Coode's design.

The dues levied have not sufficed to meet the outlay. They have amounted over the last few years to an average of about £40,000 per annum. Towards meeting the deficiency, bonds have been issued redeemable by half-yearly drawings over a period of twenty years commencing from the 30th of June, 1886, for a total sum of 4,000,000 pesetas, say £160,000.

The impulse given to the trade of the port, due to the increasing demand for the iron ore, a demand that can now be adequately met by the altered conditions of the river and its bar, is shown by a comparison of the imports and exports of the last few years.

In the year 1879–80, the imports and exports of the Port of Bilbao amounted to an aggregate of 2,000,000 tons, whereas for the year 1884–5, these have amounted to 3,500,000 tons, of which the exportation of ore alone represented over 3,000,000 tons, and in the year 1882 reached 3,600,000 tons as compared with less than 250,000 tons in 1870. During the period of fifteen years, viz., from 1861 to 1876 the total exports had only reached 2,700,000 tons. The Carlist war had just terminated at the latter date, when these mines began to be actively opened up.

To the present time there has been exported from the Bilbao River a total of over 25,000,000 tons of ore. Fifteen years ago their district was almost wholly unprovided with means of transport and facilities of shipment. The port was then only accessible to small vessels of light draught, subject to frequent delays and constant risks of crossing a shallow bar with a tortuous and ever-shifting channel. It is now, and has been for a considerable period, open at all tides to vessels from 2,000 to 3,000 tons burden, except during the severe storms which at times scourge the whole of this coast, and maintain the traditions of the once dreaded Bay of Biscay. Vessels, which were frequently detained for weeks in the river waiting for fine weather and spring-tides, are now trading with the greatest regularity, and receive such excellent dispatch at the various shipping-berths as to be able in the case of most ports to make a couple of round trips per month.

It may be hoped that sooner or later funds may be forthcoming sufficient to justify the formation of outside shelter-works, which will render the trade of the port altogether independent of stormy weather.

The left bank of the river is now the seat of smelting operations of importance. There are three distinct works with an aggregate of eight blast-furnaces of modern type, so that, in addition to

the exportation referred to, there is a local consumption of from 400,000 to 500,000 tons of ore per annum; and in the case of one of these works, that of Mr. Ybarras, a complete Bessemer plant with rail-mill has been set up, wherein steel rails are now for the first time manufactured in Spain.

From whatever point of view we may regard the matter, the work of the engineer has upon a relatively small outlay afforded most beneficial results to Spain, and to other countries. To this country there has been imported for some years about 2,000,000 tons of ore per annum from Bilbao, or nearly four-fifths of the total tonnage of foreign ores brought into Great Britain. Among the principal continental consumers are France, Belgium, and Germany. Of the entire quantity of ore which leaves the river 60 per cent. is freighted in British vessels.

Owing to the facilities now given, Bilbao ore, which in 1872 realised 35*s.* per ton, delivered at our ports (one-half the cost representing freights), is at the present time landed at South Wales (where the import is 1,000,000 tons per annum) at a cost of 10*s.* to 10*s.* 6*d.* per ton, including freight, which does not exceed 4*s.* per ton. Steel rails, which in 1873 were introduced into Bilbao for the first English line there at £15 10*s.* 0*d.* per ton f. o. b. at Liverpool, are now obtainable at the reduced price of £3 10*s.* 0*d.* to £4 per ton f. o. b. in South Wales.

Whilst many circumstances have combined to bring about so marvellous a change, a not insignificant portion of the difference is due to the causes which I have enumerated. Our manufacturers, aided by these cheap supplies of raw material, have been enabled to tide over the period of depression and anxiety which has prevailed of late, and an enduring benefit has been conferred on the industries directly or remotely connected with steel-manufacture. The benefit is a mutual one, for to Spain a new outlet has been opened for the energies of her people, affording, it may be hoped, a guarantee against the recurrence of the miserable civil wars which, in time past, have wrought desolation and misery in the Basque Provinces.

The works above described have been attended with far-reaching effects upon the Northern Provinces by the rapid conversion the district has undergone from a state of stagnation into one of industrial activity. Only a few years since the principal exports of the town of Bilbao (then the second in rank of the commercial ports of Spain) were described as consisting of wheat and flour. One of its chief articles of import, viz., dried cod, was transmitted from thence to all parts of the interior. Not

even a passing allusion was made in this account to the resources now developed, and which far transcend all the rest of its trade put together.

Colonial Railways.

The development of the Colonial possessions of our Empire has been brought prominently under our notice, by the marvellous display of their productions and material resources, which the interesting Exhibition at South Kensington, now about to close, has afforded us.

There can be no doubt that the prosperity to which our great Colonies have attained, whilst in the first place due to natural causes, such as fertility of soil, the possession of rich mineral treasures and facilities of access by sea and by rivers (advantages which have been utilized through the energy of our colonists), has been largely enhanced by, and in some cases may be said to be exclusively due to, the construction of works which it has been the function of the engineer to design and carry into effect. Amongst these, harbours, docks, canals, roads and railways, occupy a prominent place.

We have reason to be proud that our Institution is worthily represented, in the different quarters of the globe, by members who have so effectively executed the tasks entrusted to them, and have shown so much skill, energy, and fertility of resource in coping with and surmounting the difficulties, incidental to carrying out works, many of which are of great magnitude and importance.

I have thought that this occasion might be a fitting one to glance at the progress of railway enterprise in these possessions, as one of the most important factors contributing to the promotion of their wealth and comfort, and to the furtherance, not only of their own commercial industries, but also those of the Empire as a whole.

Canada.

The recent completion of the Canadian Pacific Railway traversing the confederated Provinces, under British dominion, and connecting the shores of the Pacific with those of the Atlantic, marks an epoch in the history of railways, and has brought more prominently before the world the enterprise and resources of those provinces. Nevertheless, the early history of Canadian railways, shows, that very soon after the first railways were commenced in Great Britain, and the United States, several projects were discussed for the

construction of railways in Canada. It was only, however, in the year 1837, the date of the opening of the Grand Junction Railway connecting Birmingham with the towns of Liverpool and Manchester, that the first passenger railway, viz., that from La Prairie, on the St. Lawrence River, to St. John's, on the Richelieu River, in the province of Quebec, was worked by the locomotive-engine. Its length was 16 miles; its gauge 5 feet 6 inches, with light gradients and flat curves. The Charter had been granted in the year 1832.

It was not to be expected, in a country then only sparsely populated, and having regard to the enormous extent of its territory, that the railway system should make any very rapid progress. It appears from the journals of the legislatures of Upper and Lower Canada (now the Provinces of Ontario and Quebec) for the year 1851, that, up to the end of the session of 1850, Acts of Incorporation had been granted for seventeen railways in Upper Canada and seventeen in Lower Canada, of which number (thirty-four in all), twenty grants were made subsequent to the year 1839; nevertheless we find that, in the year 1850, Canada had only 79 miles of railway completed and at work. No doubt the first great impulse towards the extension of railways in Canada was given after considerable experience had been gained elsewhere, and when the importance of this cheap and rapid mode of travelling had been confirmed, by the results of the working of the main lines then recently opened between the metropolis and the manufacturing districts of the north of England.

From 1837 to 1842 little appears to be recorded of the progress made with railway construction in Canada, and the first railway return giving the traffic results presented to the legislature was for 1844 and the two preceding years. The traffic of 1844 was represented by twenty-seven thousand and one hundred and eighteen passengers, and 12,639 tons of freight, conveyed at a cost of £11,851, this amount representing 77 per cent. of the gross receipts. At the date of the return above mentioned, (1850) no passenger railway had been constructed in the Provinces of Nova Scotia, New Brunswick, or Prince Edward's Island.

In the year 1848, Major Robinson reported on the route of the present Intercolonial Railway, between Halifax and Quebec. This railway was only begun under the Act of Union by the Federal Parliament, and completed in 1878.

In 1851, the Railway Committee had under consideration a bill for a charter to construct a railway through British Territory to the Pacific Ocean. The Committee reluctantly reported against it,

on the ground that the claims of the Indian tribes, and of the Hudson's Bay Company, to the lands had just been adjusted. The Committee in this report say:—"At the same time your committee feel bound to state their impression, that the scheme ought not to be regarded as visionary or impracticable. Your committee are strongly inclined to believe that this great work will, at some future time, should this country advance as heretofore in prosperity and population, be undertaken by Great Britain and the United States." This prediction has, as we know, been verified in its essential particulars by the recent completion, though on a modified route, and without the intervention of foreign capital, of the "Canadian Pacific Railway," the course of which is almost identical with that shown on the map, accompanying a pamphlet, issued by Major R. Carmichael-Smyth in the year 1849, in which he had advocated the construction of a trans-continental line through British territory.

The development of the present railway system synchronizes with the political life of the present Premier of Canada, Sir John Macdonald, G.C.B., dating from 1844, when there were but 14 miles in operation. Up to the time of the confederation in 1867, the longest lines under separate management, were the Grand Trunk (905 miles), constructed between the years 1852 and 1858, and notable for the great tubular bridge, built from the designs and under the direction of the late Mr. Robert Stephenson, over the St. Lawrence, affording a direct connection between Quebec, Montreal and Chicago; and the Great Western Line (303 miles), opening up important tracts of country in the west.

Canada has not been exempt from the troubles which at an earlier period beset the question of gauge in England and in the United States. The battle of the gauges was revived in 1851 in connection with the Grand Trunk Railway. Engineers were examined, and railway-men brought from the United States to give evidence. The example of the United States tended rather to confound than to simplify the solution of the problem, for no fewer than five different gauges were in use there.

In the State of New York and the Western States north of the Ohio River, the gauge was 4 feet 8½ inches; in some parts of the Middle States, 4 feet 10 inches; in the Southern States generally, 5 feet; in the State of Maine, 4 feet 8½ inches, and 5 feet 6 inches; whilst the gauge of the New York and Erie Railroad was 6 feet. The Railway Committee of the House finally adopted 5 feet 6 inches as the one, in their opinion, best adapted for the promotion of Canadian interests.

The importance of uniformity of gauge, and the commercial considerations which gave preference to the old English standard gauge of 4 feet 8½ inches have led up by degrees, as has been the case in the United States, to the conversion of most of the Canadian lines to this latter standard. There now exist only two passenger railways in Canada the gauges of which differ from the standard of 4 feet 8½ inches, viz.: The Prince Edward's Island Railway, 212 miles in length, with a gauge of 3 feet 6 inches; and the North-West Coast and Navigation Company's Railway, 104 miles in length, with a gauge of 3 feet. Out of 853 miles of narrow-gauge railways built in Canada, 537 miles have been converted into the standard gauge.

In 1867, the date of the confederation of the Provinces into the Dominion of Canada, it is recorded that there were in operation 2,258 miles of passenger railways thus distributed in the various Provinces:—

In the Province of	Nova Scotia . . .	145 miles.
" "	New Brunswick . .	266 "
" "	Ontario and Quebec .	1,847 "

For the period of ten years, 1860 to 1870, there was scarcely any increase in railway mileage in the two Provinces of Upper and Lower Canada. Since that time, and notably since the Act of Union was passed, construction in Canada has made advances with rapid strides, and *pari passû* with a corresponding general development of the resources of the country.

At the end of 1876 the mileage had more than doubled, being 5,157 miles; whilst the mileage existing in June of 1885 had increased to 10,773 miles, and by December 31st, 1885, to 11,275 miles, so rapid and steady has been year by year the growth of the railway system. At this latter date the total expenditure had been $625,754,704, with a remaining indebtedness of $20,000,000, since liquidated, towards which aid from Government, from municipalities, and from other sources, had contributed $187,000,000. About 100,000 tons of steel, and 250,000 tons of iron rails were then in service.

The earnings for the fiscal year 1884–85 were $32,227,469, and the expenses $24,015,321 on a train-mileage of 30,623,689 miles, equal to 74½ per cent. of the gross receipts, giving a return of 1¼ per cent. on the capital invested. Though this is a low rate of interest, the railways have indirectly served to augment the wealth and resources of the Dominion in a marked degree.

The eighteen years following the confederation show an average

annual increment of 312 miles of line, which must, under the circumstances of the country, be admitted to be a rapid rate of progress.

The cost of construction in the present day is considerably less than in the early days of railway enterprise in Canada. Gradients which then were considered inadmissible are now, with the increased power of the locomotive, easily surmounted, and thus the necessity for heavy cuttings and embankments, and of expensive tunnelling, is to a great extent obviated, the lines accommodating themselves more nearly to the profile of the natural surface of the ground.

Several railways are now in progress, and others have been projected, with the object of opening up large tracts of fertile country by connections with the Canadian Pacific Railway, and of equipping the Province of New Brunswick and the Island of Cape Breton. Gradients of 1 in 40 are in some instances used, but 1 in 66 may be taken as the usual limit for gradients, and a radius of 15 chains as the limit for curves.

In the pamphlet before referred to, Major Carmichael-Smyth writes with reference to the proposed railway to connect the two oceans:—This great national railway from the Atlantic to the Pacific is the great link required to unite in one powerful chain the whole English race, which will be the means of enabling "vessels sailing and steaming from our magnificent Colonies—New Zealand, Van Diemen's Land, New South Wales, New Holland, from Borneo and the West Coast of China, from the Sandwich Isles and a thousand other places, all carrying the rich productions of the East, and landing them at the commencement of the West—to be forwarded and distributed throughout our North American Provinces, and to be delivered in thirty days at the ports of Great Britain."

The realization of this project was reserved for later times. The admission of British Columbia into the Dominion of Canada in 1871, made it necessary for the statesmen who brought about that political connection to face the question of a trans-continental railway, as essential to the preservation of its unity. Hence Sir John Macdonald, under whose energy, influence and determination the enterprise has just attained its full realization, consented to make the construction of such a road within ten years one of the conditions of the compact between Old Canada and the Pacific Province.

This imperial work, brought to completion within the last few months, has been constructed entirely within the limits of the

Dominion, and being thus independent of the interference of any foreign power, constitutes the shortest route from England to China, Australia and New Zealand. It has been remarked as "a singular coincidence, and perhaps a prophetic omen of the future imperial importance of this railway, that the first loaded train, that passed over its entire length from ocean to ocean, was freighted with naval stores belonging to the Imperial War Department transferred from Quebec to Vancouver," and that "it was a remarkable commercial incident that the first car of ordinary merchandise, consigned to British Columbia, was a cargo of Jamaica sugar refined in Halifax, and sent overland to the Pacific terminus, nearly 4,000 miles in one stretch under the flag of Great Britain."

As compared with the Panama route between England and Australia, the total distance to be traversed is substantially the same, *i.e.* 12,500 miles by Panama as against 12,300 miles by Canada, with a saving, however, in the case of the latter of 3,250 miles of ocean steaming, for which about 3,000 miles of railway travelling is substituted.

The surveys were commenced in 1871, and extended over several years, under the charge of Mr. Sandford Fleming, C.M.G., M. Inst. C.E. At the same time work was commenced by the Government and continued for several years on the section which lies between Lake Superior and Winnipeg.

The Canadian Pacific Railway Company was incorporated in February 1881, under the authority of the Parliament of the Dominion, to whom was transferred the work of constructing such portions of the main line as had not been undertaken by the Government, besides conferring the right of constructing branches along the entire length of the line, of establishing lines of ships or steamers at its termini, the privilege of constructing and working telegraph lines for the business of the public, as well as for their own; whilst in consideration of the completion and perpetual operation of the railway, the Government of the Dominion granted to the Company a subsidy of $25,000,000 in money and 25,000,000 acres of land, all of which land is reported to be fit for settlement. Various other valuable privileges were accorded by the Charter.

Some variations from the originally projected route of the unexecuted portion were now decided upon, and in particular a lower pass was selected (the Kicking Horse Pass) for the crossing of the range of the Rocky Mountains, involving a considerable deviation of the line to the southward.

It is a remarkable proof of the energy which has been thrown

into all its operations, that the Company, within the short period of five years, should have built, equipped and put into operation more than 2,400 miles of new railway, inclusive of about 500 miles of branch lines. The Government has built 648 miles of the main line.

Many interesting particulars relative to the character of the country traversed, of the works which had to be executed, of the difficulties that were encountered, of the methods used to overcome them, are to be found in the official reports of General Rosser, and in "Selected Papers"[1] by Messrs. James and Macdougall, MM. Inst. C.E., Mr. Van Horne, and Mr. James Ross; they are well worthy of perusal. It was a triumph accomplished by General Rosser, the Engineer, and after him by Mr. James, aided by their assistants, and ably supported by their employers, to have completed and opened the line for traffic five years in advance of the contract time, which was the 1st of May, 1891.

Heavy works were necessitated on some portions of the route, and amongst these may be reckoned an iron bridge of 1,000 feet in length over the River Saskatchewan, and those incidental to about 270 miles of most rugged and difficult country through the Rocky Mountains; but for the most part its course lay over large tracts of slightly undulating prairie land.

Gradients are seldom formidable, as, with the exception of a short length near the crossing of the Saskatchewan river, the maximum gradients between Winnipeg and a point 4 miles below the summit-level of the Rocky Mountains, a distance of 958 miles, are only 1 in 132. The summit-level at the crossing of the Rocky Mountains is 5,296 feet above the surface of the sea, and here the gradients do not exceed 1 in 45, whilst on the British Columbian side of the range there are some provisional and temporary gradients of 1 in 22, for which it is intended shortly to substitute easier ones. Up these gradients of 1 in 22 the 33-ton Baldwin engines take an average gross load, exclusive of engine and tender, of 100 tons at 6 to 8 miles per hour. The heavier gradients are confined to the mountain section, and occur within a space of 150 miles. On the other hand, the prairie lands are so gently undulating, that light gradients prevail over those portions of the route.

Between the base of the Rocky Mountains and the town of Winnipeg, a distance of 900 miles, the railway traverses one of

[1] Minutes of Proceedings Inst. C.E., vol. lxxvi. p. 266 *et seq.*

the finest agricultural regions in the world, hitherto unopened by reason of the want of railway facilities.

Careful provision has been made against snow on the prairie section by elevating the road-bed so far above the surface of the country as almost entirely to avoid cuttings. This provision involved a great deal of earthwork, derived chiefly from side-cutting, no less than 16,000 cubic yards per mile having been used.

The record of the rate at which the building of the line proceeded is remarkable, taking into account the fact that snow lies on the ground during the four to five winter months when the rivers are blocked with ice, that the temperature in winter sinks to 40° below zero, and that rainfall in July and August is nearly incessant.

During the season extending from the 1st of June to the 1st of December, embracing a period of one hundred and fifty-seven working days, 411 miles of main line were constructed, and 388 miles of track laid and opened for traffic, under the direction of Mr. James. This may be taken as the sample and measure of what was effected on other portions.

The total length of main line owned by the Canadian Pacific Company, and extending from Montreal to Vancouver, is 2,906 miles; but including other lines owned, as also branches and leased lines, the total length amounts to 4,338 miles, provided with an equipment at the beginning of the present year (probably somewhat increased since that date) of three hundred and thirty-six locomotives, three hundred and forty-five cars of different descriptions for passenger traffic, and upwards of eight thousand cars for merchandise and cattle traffic, &c.

The fixed capital as on the 1st of July last was estimated approximately at $126,884,613, in respect of which liabilities exist in the shape of interest and rentals of leased lines to the extent of $3,110,434.

The Company is now engaged in constructing a new and large bridge over the St. Lawrence at Lachine, to be completed within twelve months of its commencement, and the 125 miles of line to complete the Ontario and Quebec Railway, and bring it direct into Montreal, will, including a very large bridge over the Ottawa River, be completed this year, though tenders were only sent in at the end of May last. This bridge, the length of which between its abutments is 3,454 feet, will consist of fifteen spans, the roadway being carried on steel and iron girders. The two deep channel cantilever spans, of 408 feet each, will give 60 feet of

clear headway for the passage of ships. The remaining spans, viz., eight spans of 240 feet, two spans of 270 feet, and three spans of 80 feet, afford 28 feet of headway, which is sufficient only for smaller craft. The contract for the superstructure has been taken by the Dominion Bridge Company, Lachine, and includes provision for about 2,800 tons of steel, and 800 tons of iron.

I have referred somewhat at length to this great engineering work, which will doubtless prove of lasting benefit, not only to the Dominion as binding together all the Provinces, and opening up therein fertile districts hitherto isolated and unpeopled, but also to the Empire, as affording an important channel of commerce between the dependencies of the British Empire and the mother country.

The line is substantially laid with steel rails of the weight of 56 lbs. per yard, and the rolling-stock generally is of the American type, as is more or less the case on the Great Western of Canada and other lines in the Provinces.

Although the introduction of railways into the Colonies of Australasia may be said to date scarcely further back than 1853, we now find some 7,600 miles in active operation, returning fair interest on the capital invested, and proving an important factor in their industrial progress, and upwards of 1,800 miles in course of construction.

The discovery of the gold-fields in 1851, which gave the first great impulse to immigration, and to the consequent growth of the towns, and of settlements on lands in the interior, led up to the necessity of providing the rapid and cheap means of communication which only railways could afford; the dearth of navigable rivers rendering communication by water impossible otherwise than by sea from port to port on the coast. The period of greatest activity in the extension of the railway system has been that of the last fifteen years, for up to the end of 1870 only 948 miles in all were open for traffic, whilst seven times that length has been executed since that date.

New South Wales and Victoria, as the most populous and wealthiest of these Colonies, have naturally taken the lead, and in point of fact are virtually on a par in respect of population served and mileage constructed.[1] The average cost per mile has been somewhat

	Population.	Miles of Railway.
[1] New South Wales, Dec. 31st, 1884	921,268	1,663
Victoria, June 30th, 1885	973,403	1,676

greater in Victoria than in New South Wales, viz., £13,672 as against £12,412 per mile, the difference being probably attributable to the circumstance of more costly works having been required to meet the conditions imposed by the respectively selected routes.

Queensland and South Australia rank next in order and importance.[1] The populations are nearly equal, the miles of railway constructed are about 14 per cent. less in the case of the latter. The cost per mile, however, in both cases is only about one-half of that of the lines in the two first mentioned Colonies, being for Queensland £6,654 per mile, South Australia £6,629 per mile.

In the remaining Colony of Western Australia railway construction is in its infancy, the first line having been opened in July 1879.

It is to be regretted that on the initiation of railways in this Continent, the question of the adoption of a standard gauge, applicable to all the Colonies, should not have been considered and determined by common consent. Whilst the three Colonies of New South Wales, Victoria and Queensland commenced their railway history nearly at the same time, each adopted a gauge differing from the others—New South Wales, the standard English gauge of 4 feet 8½ inches; Victoria, one of 5 feet 3 inches. South Australia has adopted two gauges, viz., 5 feet 3 inches and 3 feet 6 inches, and Western Australia, 3 feet 6 inches. Victoria has subsequently adopted, in the case of some of the branches, the gauge of 3 feet 6 inches. In Queensland and Western Australia all the railways have been constructed upon a gauge of 3 feet 6 inches. In Tasmania 45 miles of line have been constructed on a gauge of 5 feet 3 inches, and 127 miles upon a gauge of 3 feet 6 inches. In New Zealand there are also two gauges, one of 3 feet 6 inches, and one of 4 feet 8½ inches.

It would be an unprofitable task to endeavour to explain the conflict of opinions, which has resulted in this strange diversity of gauges over regions so closely allied to one another as these are, and it is to be feared that commercial considerations have been largely subordinated to questions of comparatively minor importance, which have claimed the attention of the respective engineers whose judgment and advice has been sought by the promoters of the various undertakings.

In the year 1872 the Parliament of Victoria was on the point

	Population.	Miles of Railway.
[1] Queensland, Dec. 31st, 1884	309,912	1,207
South Australia, June 30th, 1884 . . .	317,116	1,036

of deciding to adopt, as a general standard for the extension of some of its trunk lines, the gauge of 3 feet 6 inches. The evil was happily averted in time by the Senate, who overruled a resolution of the Lower House and fixed the gauge at 5 feet 3 inches.

The question of gauge was then the subject of keen discussion in the Colony, and in view of the divers opinions held thereupon, a communication was addressed to the Right Hon. H. C. E. Childers, Agent-General for the Colony, by Mr. Francis Lingmore, Commissioner of Railways and Roads in Victoria, requesting that the opinions should be sought of engineers here connected with broad- and narrow-gauge lines; and that the general tenor of the arguments used by the respective advocates of the gauge hitherto in use, and of the alternative gauge of lesser dimensions proposed, should be set forth in the documents submitted. Three or more engineers were consulted, and reported independently and adversely to the narrow gauge, and it may be supposed that the decision eventually come to was influenced by the opinions they expressed.

A length of 271 miles of railway on a gauge of 5 feet 3 inches had been completed, and 183 miles more on the same gauge were in course of construction, whilst three additional lines (together 144 miles), of which the gauge had not been decided, had been sanctioned by Parliament, these being in extension of the existing main lines from Melbourne to Ballarat, and to Castlemain respectively.

Of other railways, a length of 341 miles, viz., the lines from Geelong and from Ararat westward, had been proposed in connection with the authorized lines running in those directions from Melbourne, as also 126 miles from Melbourne to Sale. The construction, as it was contemplated, of these 611 miles to the lesser gauge of, say, 3 feet 6 inches, would have involved no less than four breaks of gauge, occurring at Ballarat, Castlemain, Melbourne, and Geelong, in a system of 1,064 miles of railway in all, with the certainty that that number would be extended as and when branches from lines of the existing gauge should be thrown off.

The Government Engineer-in-Chief had shown conclusively that the saving in first cost by adopting the gauge of 3 feet 6 inches instead of 5 feet 3 inches would not exceed £351 per mile. Against this had to be set the disadvantages incidental to break of gauge, and which may be shortly summarized.

1. Increased cost of transport by reason of employment in the narrow gauge of less powerful engines, and of vehicles of smaller

capacity, thus increasing the daily number of trains and that of their attendants, as required for the transport of a given volume of traffic.

2. The cost and delay incidental to the transfer of goods from the rolling-stock of the broad-gauge to that of the narrow-gauge, and *vice versâ*, the delay thence arising being specially prejudicial in respect of articles requiring rapid transit, such as luggage, mail-bags, fish, fruit, &c., the transfer of which, in many cases, would involve the sorting, reclassification, and redistribution in the different vehicles, with considerable chance of loss and breakage.

3. The necessity of having at hand at all times, at each point of contact of the two gauges, an ample supply of rolling-stock adapted to both, and inclusive of the varieties of each kind for effecting the exchange, a requirement involving the provision of a much greater amount of rolling-stock than would otherwise be necessary.

4. The more extended station-room required for accommodating the rolling-stock of the two gauges.

5. The much greater outlay incurred in the provision of rolling-stock for a system of lines of different gauge, by reason of the fact that the two classes of rolling-stock are not interchangeable, and that each section would have to be supplied with a much larger number of engines, carriages, and wagons than would be the case if these could travel over every district in the contemplated systems.

In the Report which I had the honour to submit to the Agent-General, I stated that it was desirable that the whole of the railway system in Victoria, as delineated on the map submitted (the lines before referred to), should be made to one and the same gauge. That the same uniform gauge should be maintained in the case of all future extensions and branches, unless some very special reason should exist to require and justify an exceptional departure from the rule. That looking to the extent of the railways constructed and in course of construction, in accordance with the hitherto adopted standard of 5 feet 3 inches, and looking to the cost which would be occasioned by an alteration of that gauge on the lines then completed, and by the provision of fresh rolling-stock to work on such altered gauge, it was advisable to retain the then standard, unless Parliament should deem it expedient to assimilate that gauge to that of New South Wales, in which case the ordinary English gauge of 4 feet $8\frac{1}{2}$ inches would become the standard gauge for the Colony of Victoria.

The want of uniformity between the gauges of the several

Colonies will, in course of time, no doubt be severely felt, in the restriction of traffic and increased cost of working, when contact is made between these systems.

The difficulty may, perhaps, be less appreciable in the cases under consideration (seeing that the lines are all Government lines) than has proved to be the case in England and in the United States of America, where the competition between narrow- and broad-gauge lines resulted in abstracting the traffic from broad-gauge lines and directing it over those of the narrower gauge, thus compelling the proprietors of the broad-gauge lines in self-defence to incur the cost of conversion, or of laying down a narrow-gauge track in addition to that of their broad-gauge.

One of the earliest of the United States lines thus altered was the Ohio and Mississippi Railway, 340 miles in length, with 150 miles of sidings, the original gauge of which (viz., 6 feet) was changed during the summer of 1871 to one of 4 feet 8½ inches. In all no less than 20,000 miles of railway in the United States have in course of time been altered to the standard gauge.

It is well known that in England the Great Western system has been adapted to the same old standard, for it was found that traffic made its way by circuitous routes to districts served by the broad-gauge railways, rather than encounter the obstacles interposed by breaks of gauge at Gloucester and elsewhere.

New South Wales.

In New South Wales the first railway, viz., the line from Sydney to Parramatta, 14 miles in length, was opened for traffic in the autumn of 1855, or just a quarter of a century after the railway system had established a footing in Europe. This line had been undertaken by a private company, but owing to financial difficulties encountered before completion, the Government, having obtained an Act enabling it to purchase the railway and plant, took over the line, and, at about the same time, undertook the construction of the short line of railway from Newcastle to Maitland, 19 miles in length, which had been projected by a private company. Thenceforward railway construction has been carried on almost exclusively by the Government.

There is at present one public line in the hands of an independent company, connecting with the Victorian railway system, 45 miles in length, on a gauge of 5 feet 3 inches, and paying a good dividend to the shareholders.

The crossing of the central mountain range caused considerable

delay in the progress of the construction of the three great arterial lines, leading westward and northward from Newcastle and Sydney respectively. The difficulties, however, were eventually overcome, and these main lines of railway now collect and distribute traffic over extensive districts, which had previously been only partially served by common roads of the roughest description.

The conditions attaching to the systems of railways radiating from Sydney and Newcastle are peculiar, in the sense of having to cross these rough and precipitous mountain ranges before reaching the interior plains, rendering the gradients to be encountered both numerous and severe.

The "zigzag" tracks by which some of the lines are conducted over these heights, and especially the Lithgow "zigzag" between Mount Victoria and Lithgow, by which the Western Railway ascends the mountain slopes, rising in that distance through a vertical height of 700 feet, have elicited much admiration. In this way the summit-levels have been attained by gradients not exceeding 1 in 30, and therefore workable by locomotive-engines of adequate power.

From Newcastle, the principal coal port of the Colony, the Great Northern line, from which more than 1,000,000 tons of coal are annually shipped, now runs northward as far as Glen Innes, a distance of 298 miles; and by an extension of 16 miles now in progress to Tenterfield (a border town of the adjoining Colony of Queensland), it will, before long, and on completion of two remaining short links, afford uninterrupted intercolonial communication between Sydney and Brisbane. Those links consist of the Sydney and Newcastle line, now in course of construction, and the interval of 25 miles occurring between the terminus of the Queensland line and Tenterfield. The line traverses the rich valley of the Hunter River and other lands generally that are fertile, attaining the height of 4,500 feet above the sea-level.

The Great Southern Railway, commencing at Sydney and passing through Goulburn, Junee, and Wagga Wagga, arrives at Albury, the frontier town separating New South Wales from Victoria, traversing 387 miles of country. The last short link of this intercolonial line between Sydney and Melbourne, including a mile or two of railway and a temporary bridge over the River Murray, was finished at midsummer 1883. Unfortunately the difference between the standard gauges of the respective Colonies (4 feet 8½ inches and 5 feet 3 inches) necessitates a break in the transport at this spot which is likely to occasion some expense and inconvenience in the future, when the progress of the Colonies comes to

demand a considerable amount of interchange of commodities in the shape of merchandise and minerals.

The South-Western Railway, branching off at Junee, is open to Hay, 454 miles to the south-west, and it is expected will ere long be extended to the borders of South Australia.

The Great Western line, also starting from Sydney, passes through Bathurst, Orange, Wellington, and Dubbo, and has reached the town of Bourke on the River Darling, distant 503 miles from Sydney, thereby opening up the whole of the extensive pastoral regions of the north-west, of which it practically forms the metropolis. An authorized extension of about 360 miles, commencing at the town of Orange, will strike the River Darling at Wilcannia, some 200 miles below Bourke, and open up to settlers a further most extensive tract of country. At the commencement of 1885, 1,618 miles of line were open for traffic, 391 miles in course of construction, and 1,324 miles more were authorized by Parliament.

The progress of railway enterprise has of late years, and notably since the year 1870, been advancing with accelerated speed, and the capital expended on constructed lines has been yielding an increasing return in the shape of interest, a return which for the year 1884 amounted to 4½ per cent. on the total expenditure of £20,088,240.

Under these circumstances, and having regard to the contingent influences of railway extension as effecting close, rapid, and cheap connection between the remote districts and the seaports and the market of settled districts, adding greatly, as has been the case, to the wealth and resources of the Colony, the credit of the Government has been such as readily to command the loan of money at the very moderate rate of 4 per cent. per annum. Such credit is further justified by the fact that the value of trade per head of population, viz., £45 17*s.* 4*d.* per annum, was considerably higher at the close of the year 1884 than in that of any of the other Australasian Colonies.

The Trunk lines are to be connected by railways, which will unite the whole system of the Colony into a vast network, forming feeders to the main lines, and completing railway communication as already mentioned between the several Colonies of the Australasian Continent.

Many important and costly engineering works in the shape of iron bridges over rivers and creeks have been constructed, and quite recently a contract has been entered into with an eminent firm of American bridge-builders, for the construction of a large

iron viaduct over the Hawkesbury River of seven spans of 415 feet between the centres of tie piers for a double line of railway.

The contractors undertake to furnish the ironwork and erect the bridge *in situ*, taking all risks connected with the sinking of foundations, as well as those otherwise incidental to the due completion of the structure, for a specific sum of money. It appears that their tender was considerably lower than that of any English or foreign firm. Nevertheless, it is a remarkable circumstance that the sub-contracts for the material—ironwork and steel—have, as it is understood, been placed with English or Scotch manufacturers, whence it may be inferred that the difference in the amounts of the respective tenders are presumably due in the first place to differences in appreciation of the contingent expenses that may have to be incurred, in connection with foundations, &c.; and, secondly, to designs differing considerably in the weight of the material to be employed, the contractors having been allowed to work out their own designs subject to certain specified conditions.

Victoria.

For the various railway lines forming the system carried out in the Colony of Victoria the gauge of 5 feet 3 inches has now been adopted. Under the plea of diminishing their first cost and of reducing working expenses, the proposal to which I have already adverted, that of resorting to light lines of narrow- (3 feet 6 inches) gauge, was at one time strongly advocated and seriously entertained, although disapproved of by the Government Engineer. This project related not merely to contemplated branch or subsidiary lines, but also to extensions of trunk lines, which had been sanctioned by, or were awaiting the sanction of, Parliament.

Fortunately for the Colony time was allowed for a full and careful consideration of the matter, and the disadvantages, seen to attach to the introduction of a second gauge, led to the wise decision of laying down the trunk lines in question on the heretofore adopted standard gauge, and of constructing them in a substantial manner. A serious evil was thus averted.

The development of traffic on these lines has fully justified the resolution then adopted. This has been so considerable, as to show that light railways would have been unsuitable for so large and increasing a traffic, whilst the numerous breaks, which at different points of the system would have occurred by contact of the two gauges, would have caused great interruptions, delays, and increased cost in working. The characteristics of the country,

which is comparatively level, have generally permitted very easy gradients. In a few instances, however, some steep ones occur, but the highest elevations surmounted do not much exceed 2,450 feet above sea-level.

The railway system in this Colony was inaugurated in 1856, by the opening of the line from Melbourne to Sandridge. The line from Melbourne to Geelong, then in course of construction, was not available for traffic until the following year. From that period we may date the steady growth of the systems now developed.

At the present time all the railways are under State control. They are vested in three commissioners, who are a body corporate with perpetual succession under a common seal, and hold office for a term of seven years, at the expiration of which they are eligible for reappointment. They are charged with the duty of constructing such lines of railway as are authorized by Parliament, and of maintaining works, and controlling and managing all the lines, subject in some respects to the control of Parliament.

The Hobson's Bay Railway, now a double line of 16½ miles in length, was originally projected, and was worked for many years, by a private company. It was only taken over by the Government in 1878, the price paid being £1,320,800, or £8,000 per mile. The line from Melbourne to Geelong was purchased from a private company by the Government in 1860.

In the summer of 1884 the extent of railways open was 1,624 miles, consisting of 205 miles of double and 1,419 miles of single line, constituting a compact network, extending from the important seaports of Melbourne, Geelong, and Portland Bay as a base, and embracing a large area of the Colony.

Taking Melbourne as the principal terminus, three main arteries with lateral interlacing branches may be said to proceed therefrom, viz., the north-eastern, leading to the frontier of New South Wales on the River Murray at Albury, there joining the line to Sydney; the northern also reaching the Murray at Echuca, and shortly to be continued to Swan Hill, a town lower down the river; and the western leading to Portland viâ Geelong and Ballarat, and destined to become the means of direct communication between Melbourne and Adelaide on completion of the line now under construction in South Australia, also an authorized line in extension of the existing line from Ararat to Portland. The eastern system connects Melbourne with Sale (127½ miles). In addition to the above is the system of suburban lines radiating from Melbourne.

The lines already opened had cost £18,752,876, or an average

of £11,549 per mile. Besides these, 71 miles were in progress, authorized to cost £382,578, and 1,201 miles more had received the sanction of Parliament at an authorized cost of £6,804,730.

Of the 1,624 miles then open, 268 miles may be taken to represent trunk and suburban lines of a specially costly character, inclusive of 101 miles of double line between Melbourne and Sandhurst. On these the sum of £9,673,841 had been spent, giving an average of £36,093 per mile, including a heavy outlay on the station at Melbourne, whilst the remaining 1,356 miles of branch and cross country lines had cost £9,079,035, or an average of only £6,700 per mile.

The net revenue accruing on the entire capital expended on railways opened for traffic was, according to the return for the half-year ending the 30th of June, 1884, at the rate of 4 per cent. per annum, a satisfactory return for a country having a population of only ten to the square mile.

Queensland.

The introduction of railways into the Colony of Queensland dates from the year 1864, when a commencement was made with the line which connects Brisbane with the western cities of the plains, and with those on the southern border of the Colony of New South Wales.

It was decided at the outset that 3 feet 6 inches should be the standard gauge, and this gauge has been adopted throughout.

The greatest obstacle to railway communication with the interior was the precipitous main coast mountain range; but this has been, at considerable cost, surmounted by gradients not steeper than 1 in 50 carried around the spurs of the mountains, through tunnels, and across deep gorges.

1,339 miles are open for traffic.
139 „ are under construction.
279 „ have legislative sanction.

They constitute three main groups—northern, central, and southern—their general direction being westward from their respective termini of Townsville, Rockhampton, and Brisbane on the coast. Connection with the New South Wales system will be effected in the neighbourhood of Tenterfield by two short links which have been authorized, and of which one link is now under construction. Here the break of gauge will occur, subjecting the direct through traffic between Melbourne and Brisbane to two

breaks during the journey. Extensions further westward are contemplated.

The cost of the lines now at work has averaged £6,654 per mile. The cost per mile of lines has ranged from £2,034 on the Clermont branch to £21,019 on the Brisbane and Ipswich line. The working expenses have averaged 52 per cent. on the gross receipts, and the interest returned on capital in the shape of net earnings has been a little under 2 per cent.

All are Government lines. The districts which are, or will shortly be, served, bear but a very small proportion to the area of the entire Colony, so that there remains a vast field for future enterprise as population increases.

In 1880 a company of English capitalists sought from the Government the concession to make a line on the "land grant" principle from Charleville to Point Parker on the Gulf of Carpentaria; the company to receive from 10,000 to 12,000 acres of land for every mile of railway constructed. The agreement come to was, however, negatived by Parliament, who declined to entertain any land-grant railway system on a large scale.

Amongst the projected lines is one to Brisbane, with the Gympie gold-fields, passing through fine agricultural districts and forests abounding with valuable timber.

South Australia.

The first locomotive line opened in the Colony of South Australia was in 1856, a line of 7 miles, connecting the city of Adelaide with the port. Its gauge was 5 feet 3 inches. Thenceforward railway construction made steady advances, although much yet remains to be done towards the opening up of extensive, but at present sparsely populated, districts. The total length of line which was open for traffic on the 30th of June last year was 1,076 miles. At that date an additional length of 407 miles was under construction, and a further length of 315 miles authorized.

It is to be regretted that a diversity of gauge should have been introduced into this Colony also. We find that of the 1,798 miles completed, under construction, and authorized, 521 miles are on the 5 feet 3 inches gauge, and 1,277 miles are on the 3 feet 6 inches gauge.

The narrow-gauge lines are arranged in three groups, involving as many breaks of gauge, the first group extending northwards and westwards from the town of Terowia, forming a junction there with the northernmost extension of the broad-gauge system; the

second extending westward to the coast from or near the broad-gauge line at Stockport; and the third starting from the southern terminus of the broad-gauge system at Border Town, and proceeding southward to Mount Gambier with lateral lines, striking the coast at two points, viz., Lacipede Bay and Rivoli Bay.

It fortunately happens that by the central or broad-gauge system radiating from Adelaide, the connection between that city and the lines in the Colony of Victoria will be effected by a continuous broad-gauge line, so soon as the lines now under construction in the two Colonies meet at Border Town, and thereby afford a direct route between Melbourne and Adelaide free from interruption.

The lines now in operation appear to have cost on an average, inclusive of stations and rolling-stock and other plant, about £7,250 per mile. Few physical difficulties have to be encountered; hence the very moderate cost. With the exception of two suburban lines near Adelaide, all are the property of the State.

As an arm (149 miles in length) of the northern group of lines on the gauge of 3 feet 6 inches, the contract has been let for a railway from Petersburg, proceeding in a north-westerly direction to the border of New South Wales, where it will eventually come into contact with the gauge of 4 feet 8½ inches of that Colony. It seems intended to construct this extension at the least possible cost, and as much as possible on the surface, laying it with 41-lb. flanged rails spiked on to wooden sleepers, with scant provision of ballast; constructing no intermediate stations, but providing simply platforms and sidings for local traffic; the speed of passenger trains to be limited to 15 miles, and that of goods trains to 12 miles per hour.

Western Australia.

Railway enterprise in the Colony of Western Australia was initiated in 1878 by the completion of a local line 34 miles in length, on a gauge of 3 feet 6 inches, connecting the town and mining district of Northampton with the port of Geraldton, Champion Bay, at a cost on an average of £4,364 per mile. Unfortunately, owing in great part to the fall in price of copper and lead, and consequent prostration of the mining-industries, the traffic has proved unremunerative.

Indeed, as yet very little progress has been made towards opening up the interior of this large Colony, for the only other public line which has been opened for traffic is the main line termed the "Eastern Railway," commencing at Fremantle, a seaport town at the mouth of the Swan River, 12 miles below Perth, the capital, and terminating at the town of York, the entire length being

68 miles. The average cost of the first 20 miles was £6,223 per mile.

With reference to this railway, the Engineer-in-Chief remarks, in his report of the 24th of August, 1885, that "no more utterly false economy can be made on a main trunk line of railway as this Eastern Line, than that of cheap construction, regardless of the cost of future working expenses, so long as the capital outlay at the first be kept down, and this is what unfortunately has been the case here." He points out that had a small additional outlay been made in trial surveys and sections, to ensure the best route being selected, and an additional expenditure incurred in earthworks, a railway might have been made of which the working expenses would at the least have been one-third less than they now are, and must continue to be, owing to the severe gradients and curves which now exist.

Doubtless this warning will not be lost sight of in view of the future development of the railway system of Western Australia; and it may be worthy of attention by the Government of South Australia in connection with the cheap railway, which I have just mentioned as having been projected in that Colony.

Various projects of new lines and extensions have been submitted and entertained by the Government. Amongst these a proposal by an English syndicate for a land-grant railway on a gauge of 3 feet 6 inches from Perth to Geraldton, a distance of over 250 miles, has been accepted and a company registered. 12,000 acres of land are to be granted for every mile constructed.

New Zealand.

In proportion to the extent of territory comprehended by the two principal islands of New Zealand, the length of the Government railways open for traffic is very considerable, and affords remarkable evidence of the rapid development of the resources of this Colony. In a recent Report (1886) the length is stated to be 1,538 miles.

It was only after the passing of the Immigration and Public Works Act in 1870, that their construction was commenced and prosecuted on a large and comprehensive scale. It will be remembered that the colonization, in the case of the early settlements, commenced in 1839, and was subsequently much retarded by a long and arduous struggle with adverse circumstances, and notably the desultory and bloody wars waged with the natives, until the power of the Maoris was finally broken in 1881.

The New Zealand Government railways have cost, on an average, somewhat over £8,000 per mile; for the year ending the 31st of March, 1885, the interest yielded on the capital

expended on their construction was at the rate of 3 per cent. per annum.

By the above-mentioned Act, 3 feet 6 inches was established as the standard gauge throughout. The intention at the time was that the lines should be of light and cheap construction, and worked at low speeds.

In addition to the Government lines, there are 91 miles of comparatively short private lines, some of which are being bought up by the Government.

In the North Island the lines serve four isolated districts, running for the most part nearly parallel with the east and west coasts, at no point penetrating into the interior more than 30 miles. They terminate respectively at the ports of Auckland on the north, Wellington on the south, Napier on the east, and New Plymouth and Wanganui on the west.

By reason, too, of lofty mountain chains in the South Island the slopes of which rise gradually from the coast, the railway system here is virtually confined to skirting the eastern littoral, and consists substantially of a single trunk line, commencing at the southern Port of Invercargill, and serving, *en route* to its northern terminus near the town of Waiáu, the eastern seaports of Dunedin, Oamaru, Timaru, and Christchurch, throwing out on its course short lateral branches toward the mountain ranges. The connections across the island are, however, about to be made, and workable locomotive lines selected to traverse the mountain ranges.

The so-called east and west route, of 95 miles, will afford direct communication between Greymouth and Christchurch, crossing, by the Arthur Pass at an elevation of 2,530 feet, with gradients of 1 in 50 and 1 in 60, and 7½-chain curves. Twenty-four tunnels, of an aggregate length of 5½ miles, and fourteen viaducts, will raise the cost per mile to more than double the average cost of those already constructed.

The projected West Coast and Nelson Railway (154 miles), proceeding from Greymouth in a north-north-westerly direction, will unite that town and district with the Port of Nelson. This line involves about 3½ miles of tunnelling, and nearly 2 miles of bridging. It is anticipated that its construction will materially stimulate the coal and other mineral industries, as well as the agricultural on the west side of the island. Rails of from 40 lbs. to 53 lbs. per yard have been, I understand, generally laid down, and, on some steep gradients, rails of 70 lbs. per yard.

The "Fell" system, for working steep gradients, has been applied on the line connecting Wellington with the Wairarapa Plains, where, for the purpose of diminishing a heavy cost of

tunnelling in crossing a mountainous ridge, the Colonial Engineer laid out a section of 2½ miles on a gradient of 1 in 15. This is worked by Fell engines, the adhesion due to the weight of the engine being, as is well known, supplemented by that derived from the pressure of horizontal wheels against a central rail. Engines of 37 tons weight take up this incline a train of 53 tons, at 6 miles an hour, at a cost of 5*s.* 2*d.* per train-mile. At the present day such a gradient would probably be worked to greater advantage on the modified rack-rail and pinion system of Abt. Useful particulars are given of this work in the Paper by Mr. Maxwell,[1] and in the report of the discussion which arose upon it.

Tasmania.

The railway system in Tasmania is at present in its infancy. Up to the year 1884 only 215 miles of railway were open for traffic, and 159 miles under construction. Unfortunately this Colony also is afflicted by diversity of gauge.

A main trunk line, 133 miles in length, trending nearly due south, connects the town of Launceston, on the tidal river Tamar (from whence steamers run to the principal Australian ports) with Hobart, the capital and chief seaport on the southern coast, interrupted, however, by a break of gauge at Evandale, the point of junction with the Western Railway, some 6 miles south of Launceston. Of the total length of 133 miles, 127 miles are on the gauge of 3 feet 6 inches, and 6 miles on the gauge of 5 feet 3 inches, or "western," gauge. This line was undertaken by an existing company under a contract with the Tasmanian Government, who gave a guarantee of 5 per cent. for thirty years, on a cost not exceeding £650,000, the Government retaining the power to purchase it at any time on twelve months' notice.

The second, or "Western" line, connects the two northern ports of Launceston and La Trobe, being 82 miles in length on a gauge of 5 feet 3 inches, passing through the town of Deloraine. The portion between Launceston and Deloraine was constructed by a company, and opened for traffic early in 1871, but eventually taken over by the Government in the summer of 1872. It cost between £9,000 and £10,000 per mile. The remaining portion, also undertaken by a company, was only partially opened in 1871, and collapsed from want of funds. In 1882 the Government came to the rescue, purchased it for £120,000, and completed and extended it 5 miles further to Formby, near the mouth of the

[1] Minutes of Proceedings Inst. C.E., vol. lxiii. p. 50.

River Mersey, in all a distance of 37½ miles. Various branch lines, amounting to an aggregate of 159 miles, are now under construction, and further extensions are in contemplation.

CAPE OF GOOD HOPE.

The railways in the Colony of the Cape of Good Hope have been laid out on a gauge of 3 feet 6 inches, and the greater part of them are in the hands of the Government, who at the commencement of the present year owned the 1,599 miles then open for traffic. The three systems into which they have been classified—the Western, the Midland, and the Eastern, proceeding from the respective ports of Cape Town, Port Elizabeth and East London, converge towards the diamond fields.

The works have been executed, partly by contract and partly departmentally, at a total cost of £14,371,306 sterling, which is distributed over the three systems in the following proportions.

	Miles.	£.
Western	718	5,927,104
Midland	589	5,304,473
Eastern	292	3,139,729
	1,599	14,371,306

The average cost has thus been £8,980 per mile, inclusive of stations, rolling-stock, and plant. The Western system has been the least costly, the expenditure having been £8,225 per mile; that of the Midland has been £9,006, and that of the Eastern £10,752 per mile.

The lines have been laid, in general accordance with English practice, on wooden sleepers, firstly up to 1873 with light rails, and subsequently, under the advice of Sir Charles Hutton Gregory, K.C.M.G., Past-President Inst. C.E., the Consulting Engineer to the Government, with 45-lb. rails, and later on with 60-lb. rails, these last having been adopted for the last extension of 562 miles. The decay of wooden sleepers having proved rapid, trials are now being made of wrought-iron sleepers both of the trough and bowl form.

The Western Railway, running in a north-easterly direction towards Kimberley, traverses an elevation of 4,572 feet above sea-level, whilst the Eastern line crosses a range at a still higher elevation, viz., 5,446 feet.

On all three lines there occur severe gradients ranging as steep as 1 in 40, over which the traffic is conveyed by English locomotives, of which the general type now apparently preferred is a six-wheel coupled engine with four-wheel leading-bogie, the driving-wheels being 3 feet 6 inches in diameter, the cylinders

15 inches in diameter, the length of stroke 22 inches, and weight 30 tons. These are said to take nine vehicles up the gradients of 1 in 40. Clark's chain-brake, and, more recently, the simple vacuum-brake, are in use for controlling the speed.

Beside the Government railways, 150 miles belong to private companies. There are also 30 more miles in progress, to be completed this year, at the end of which there would then be 1,780 miles in all open for traffic.

The Government lines entail an annual charge on revenue of £635,954, the net proceeds serving (in 1885) to reduce this burden to £238,463. It would appear that the Eastern system is the least remunerative, and, in fact, that the excess of cost of maintaining and working expenses above receipts comes as a charge upon the revenue of the Colony, an excess which it is thought will amount, taken on the basis of the results of the first three months' working of the present year, to about £41,000. The loss is attributed mainly to the severe ox-wagon competition which the goods traffic encounters, estimated to amount over all the lines to no less than £50,000 a year. Other causes, no doubt, operate in the same direction, and notably the general depression of trade, and the circumstance of the line being to a certain extent handicapped by its greater cost as compared with the others.

Progress, in regard to further railway extensions in the Colony, has recently been slackened, in view of the financial results and present stagnation, but it may be hoped that these obstacles will be removed when a general revival of business sets in.

Natal.

The Government of the Colony of Natal possessed at the close of last year 116 miles of railway, on a gauge of 3 feet 6 inches, open for traffic, since which date the main trunk line to Ladysmith has been completed, making the total length of line now working 217 miles. Extensions are contemplated up to the borders of the Transvaal, and the Orange Free State.

The traffic for the year 1881, when only an average of 98½ miles was open, yielded a net profit of £63,159, which more than covered the interest chargeable at that time against open railways (£54,000); but in the succeeding years, a great falling off has occurred, which, as the result of five years' working, has placed the railways as indebted to interest account to the amount of £152,000. This falling off is partly attributable to the loss of the revenue derived from the carriage of material for extensions, partly to a large reduction upon the rates on the traffic, which is the principal

support of the railways, and largely to the severe competition with ox-wagon traffic.

On the whole, the railways have earned an annual average return of £2 3*s.* 2*d.* per cent. upon the capital. It is considered, however, that the balance of interest has been far more than repaid to the Colony by the convenience, facility and economy, enjoyed by the public, in respect of the conduct of both goods and passenger traffic, by reason of the construction of its railways.

Ceylon.

The railways in Ceylon have been constructed by the Government of that Colony, under the advice of Sir Charles Hutton Gregory, who was appointed their Consulting Engineer in 1856, on the demise of Mr. James Meadows Rendel. A uniform gauge of 5 feet 6 inches was fixed for all the lines. At present the aggregate length of railways open for traffic is 177$\frac{3}{8}$ miles.

The construction of the main line from Colombo to Kandy, (74$\frac{1}{2}$ miles), originally projected by a company in 1847, was not actually commenced until 1863, and was opened for traffic in 1867. The cost was 233,354 rupees per mile. Twelve years later, viz., 1879, a line 27$\frac{5}{8}$ miles in length, following the seashore, was completed to Kalutara. This was for the most part a surface-line without heavy works, other than the two large lattice-girder bridges, each about 600 feet in length at Panadure and Kalutara respectively. It cost 79,356 rupees per mile. In 1874 a branch of 17 miles, leaving Peradeniya, at 70 miles from Colombo, and constructed at a cost of 157,334 rupees per mile, was opened for traffic; it terminated at Nawalapitiya, at a level of 1,913 feet above the sea. Subsequently, communication by rail was effected in 1880, between Kandy and Matalé, 17$\frac{1}{2}$ miles, at a cost of 193,826 rupees per mile; and in 1885, between Nawalapitiya and Nanu Oya, 40$\frac{3}{4}$ miles, at a cost of 261,607 rupees per mile—this latter being in extension of the above-named branch, proceeding from the Colombo and Kandy line.

In considering the high average cost per mile of the Ceylon railways, it must be borne in mind that, with the exception above stated, all the lines traverse mountainous districts, and are exposed to a tropical rainfall, varying from 80 to 200 inches per annum, the maximum being reached at certain points on the Nanu Oya extension.

On the line from Colombo to Kandy, occurs the Kadugannawa incline of 1 in 45, 12 miles in length, rising to an altitude of 1,618 feet above sea-level, whilst the Nanu Oya extension rises by

inclines of 1 in 44, aggregating over 28 miles in length, or 69 per cent. of that extension, to a level at Nanu Oya of 5,292 feet, while the abrupt nature of the hill-sides traversed rendered the adoption of curves of a radius of 330 feet compulsory, for the sake of economy.

The bank-engines which have been used to assist the passenger and goods trains up these steep inclines are six-wheel coupled outside-cylinder engines, with a fixed wheel-base of 9 feet 6 inches, and wheels 4 feet 5 inches in diameter, and a weight of 32½ tons on the driving-wheels. The cylinders are 17 inches by 26 inches, and the heating surface of the boilers is 1,342 square feet. The loads usually allotted to the goods engine, and its assistant bank engine, consist of eighteen loaded wagons of about 11 tons each, and two brake vans; say about 220 tons in all.

The types of goods engine in use, are inside-cylinder four-, and one six-coupled, with four-wheel bogie in front; and they are capable of exerting about two-thirds the tractive power of the bank-engine.

The total capital expenditure up to the 30th of June, 1886, has been 36,304,133 rupees, giving an average cost per mile of 204,674 rupees. Of this amount, however, more than one-half has been paid off, leaving 14,052,464 rupees, on which interest has to be paid, and a sinking-fund to be provided.

Mauritius.

The sugar-producing Colonies of Mauritius, Jamaica, Barbadoes, Trinidad, and Demerara, have to a limited extent been provided with railways, used chiefly for the transport of sugar to the ports, and for goods up to the estates in the interior.

In Mauritius two main lines of railway, on a gauge of 4 feet 8½ inches, laid with 74-lb. rails on wooden sleepers, were undertaken by the Government, each commencing at the Port of St. Louis on the west coast.

The North line, about 34 miles in length, performing an inland circuit approximately parallel to the coast of the northern half of the island, and terminating at the eastern port of Grande Rivière; and the Midland line, 35 miles in length, striking in a south-easterly direction into the heart of the island, with its terminus at Mahebourg on the east coast, the two together forming a horse-shoe of about 70 miles in length from point to point.

They were constructed at an average cost of £21,876 per mile, and have been open for traffic more than twenty years, the funds being furnished by Government, partly from surplus revenue, and

partly by the issue of 6 per cent. debentures secured by a sinking fund.

Two branch lines have since been constructed; the one to Savanne, issuing from the Northern Railway, the other to Moka from the Midland.

The Midland Line alone possesses special interest, from the engineer's point of view, by reason of the heavy gradients and sharp curves which the features of the country traversed by it have imposed. Midway between its termini a range has to be crossed at a summit-level of 1,822 feet; this is attained by continuous gradients ascending from the coast lines, most of them ranging between the inclinations of 1 in 27 to 1 in 48. The traffic has been worked by heavy eight-coupled tank engines, with wheels 48 inches in diameter, which take up loads of about 100 tons at 10 to 12 miles per hour.

Jamaica.

The mountainous configuration of the Island of Jamaica constitutes a barrier to the construction of numerous railways.

The first line in Jamaica was built by a private company in 1843–45, from Kingston to Angelo, and was extended to Old Harbour in 1869, the gauge being 4 feet 8½ inches, the length of the two together being 24 miles. Traffic for a time was virtually suspended, consequent upon financial difficulties and the road having fallen into a bad state of repair. On its purchase by the local Government in 1879 for the sum of £90,000, the line was reconstructed, and extended to Porus and Ewarton, under the direction of Messrs. Sir John Hawkshaw, Son, and Hayter, the Consulting Engineers. The length of the lines at present open for traffic in the island is 63 miles, the average cost having been £5,350 per mile for the Porus, and £16,650 for the Ewarton extension, respectively, the latter having very heavy works.

A special feature in these works has been the extended use of concrete, of which material the viaducts, bridges, tunnel-lining, culverts, and station buildings have been built, stone of good quality and skilled labour being difficult to obtain.

Owing to the depressed state of the Colony, and especially of the sugar-industry, intensified by prolonged droughts during the years 1880 to 1884, the direct returns have fallen short of what were expected; but the lines have without doubt indirectly contributed to the general welfare of the Colony.

Trinidad.

The island of Trinidad had 54¼ miles of railway open in 1885, all in the hands of the Government.

The opening of the first section of 16 miles took place in 1876. It connected the capital, the "Port-of-Spain," with Arima, passing through "St. Joseph," from whence a railway, recently completed, proceeds southwards through a sugar-growing district to the port of San Fernando on the southern shore of the Gulf of Paria. A branch goes off from this line to Princes' Town.

The net receipts for the year 1885 gave a return of 2·15 per cent. on the total capital expended on the railways.

A project is now on foot, believed to be favourably entertained by the Government, for a large extension of the system to further open up the forests and fertile districts of the interior, to be undertaken by a private company on the basis of a grant of rich and fertile crown lands, which may be expected to yield ultimately a good profit to the European capitalist, by the cultivation of the sugar-cane, the cocoa-tree, and the coffee-plant.

Barbadoes.

Barbadoes possesses one railway only, on a gauge of 3 feet 6 inches, and 24 miles in length, belonging to an English company; it was fully opened in December, 1884. It commences at Carlisle Bay, the principal and only sheltered port on the south-west of the island, taking the course of the St. George's Valley, striking the east coast at Cousett's Bay, and thence following the coast line to Belle Plain, in the district of Scotland. The line has cost about £200,000, on which the Government has guaranteed, for twenty years from the date of completion, an annual payment of £6,000, equal to 6 per cent. on £100,000, applicable for the Preference shares. The traffic, almost entirely sugar, is subject to considerable fluctuation, and has been injuriously affected by the general stagnation of trade, the competition with bounty-fed sugar, and the drought of the present year. Nevertheless, the proceeds have sufficed to pay the interest on its bonds, and for the year 1885 a dividend of 2½ per cent. on its Preference (£5) shares.

Demerara.

The railway in Demerara, of which the gauge is 4 feet 8½ inches, skirts the coast over the low and level lands, extending from George Town to Mahaica. It is 24 miles in length, and traverses the extensive sugar plantations of that district. It was started as

early as 1848, but not opened throughout until 1862. On its capital of £280,000 (a sum of £115,000 of which is represented by 7 per cent. Preference, and the balance by ordinary shares), the dividends have, until quite recently, been good but fluctuating, according to the yield of the estates. They have reached as high as 8 per cent., but last year, which has been an exceptional one, the dividend fell to 2½ per cent. The engineering works have not presented any feature of special note.

Malta.

In this comparatively small dependence of the British Empire, no considerable development of railway enterprise was possible, or to be considered necessary. Its insular condition allows of access by water for the small amount of traffic passing to and from Valetta to different places along the coast. The only existing railway in the island is a line of metre-gauge 7 miles in length, and ruling gradient of 1 in 40, constructed and owned by an English Limited Liability Company, under a concession of the Maltese Government, dated the 28th of July, 1880. It connects the port of Valetta with Notabile, or Civita Vecchia, the old capital in the interior of the island. It is furnished with rolling-stock of approved English construction.

In the terminal tunnel, 1,000 yards in length, passing under the exterior and interior lines of fortifications surrounding Valetta, extensive works, designed under the orders of the War Office, have been constructed for the purposes of defence and of destruction, either permanent or temporary, as may be desired. The line was opened for traffic on the 1st of March, 1883.

The authorized capital is £60,000, of which (in June, 1884) £49,830 had been issued and fully paid up, and debentures carrying interest at 7 per cent. to the extent of £30,000 had been issued. The cost of construction and equipment of the line, including incidental expenses, is stated to have been in all £80,785.

The traffic is considerable and increasing, but as the fares are low, the expenses of working, including the interest payable on the debentures, have so far exceeded the income.

I had at one time contemplated reference to the Indian Railways, of which the aggregate length now open for traffic amounts to between 12,000 and 13,000 miles, but I found that the consideration of so large a subject would impose a heavier tax on your time and attention than would be proper in an address of this kind.

The extent of the Colonial Railways now in operation, and to

which I have been referring, amounts to nearly 21,000 miles, carried out partially by private enterprise, but mainly as Government undertakings.

From the latest returns it would appear that the population of these several Colonies amounts to, in round figures, 14,000,000.[1] It will, therefore, be seen that though the railway-mileage is small in respect of area of territory, it is very large when considered in respect of population, the accommodation afforded being about 1 mile to every six hundred and fifty persons, as against 1 mile to one thousand nine hundred and twenty-five persons in the United Kingdom.[2]

It is clear from the facts I have put forward, as to the returns on capital expended, that such a system could not have been built up without Government aid, afforded either directly by departmental intervention or indirectly by guarantees, or subsidies, or by large land grants.

Colonial experience would, on the whole, seem to tend more and more to the conclusion, that the railways should be constructed and worked at the cost of the local Governments. It may, however be questioned whether the working of the lines might not, in some cases at least, be leased, under proper conditions, to private companies, with advantage to the State. The example of the Canadian Pacific Railway, partly constructed by Government, partly by a limited company, and now worked, and to be worked, by that company, will be watched with much interest, as likely to afford a satisfactory solution of a problem on which there exists great diversity of opinion.

[1] The actual figures in 1884 were as follow:—

Dominion of Canada	4,750,000
New South Wales	921,268
Victoria	973,403
Queensland	309,912
South Australia	317,116
West „	33,000
New Zealand	564,304
Tasmania	130,541
Cape of Good Hope	1,122,000
Natal	424,495
Ceylon	2,758,529
Mauritius	370,766
Jamaica	580,804
Trinidad	153,128
Barbadoes	171,860
Guiana (Demerara)	257,473
Malta	156,675
	13,995,274

[2] The figures for 1884 being: population (estimated) 36,500,000; miles of railway open, 18,962.

Continuity in the methods of management, and the retention in service of trained and competent officers would, it may be thought, be better secured under a permanent board of management, than under control of a ministerial department liable to change in accordance with the political views which at the time may chance to predominate, and which might tend to influence the selection of competent railway employees.

Nile Irrigation-Works.

Although the works now in progress in the Delta of the Nile, under the direction of Colonel Scott Moncrieff, R.E., are not colonial works, they are well deserving of notice as having been executed under English engineers, and having already been productive of important benefit to Egypt.

It will be remembered that the great weir, spanning the Damietta and Rosetta branches at the apex of the Delta (commenced in 1847 and completed in 1862), was intended to hold up the waters of the Low Nile some 4½ metres, and to divert them for irrigation purposes into the great system of canals which water the adjoining provinces; and that it failed through alleged defective foundations, and was found to be valueless except for regulation of the flow of water into the two branches of the river. The cost of its complete restoration or reconstruction was estimated to exceed £1,000,000 sterling. The work accordingly had been postponed as being beyond the financial resources of the Government.

Three years ago, however, Colonel Scott Moncrieff, who had had great experience in the conduct of irrigation works in India, was appointed Inspector-General of Irrigation, with full powers to act without being hampered by foreign interference, and was allowed to select his own staff of officers. For this purpose a grant of £1,000,000 was accorded him by the Powers for the general purposes of irrigation.

Believing that the foundations of the weir might be trusted, he came to the conclusion that it might, at a comparatively small expense, be strengthened, and with the aid of some subsidiary works, and notably the construction of a second dam, eventually be made capable of holding up 4½ metres of water, in two drops of 2¼ metres each, thus securing a water surface never lower than 14 metres above sea-level. At the same time, measures were proposed for improving the irrigation, including a rearrangement of the watercourses, and cleansing them from the silt which had choked up many of the channels.

Accordingly the closing of the Damietta branch, which theretofore had not even been supplied with gates, the strengthening of the foundations and floors of both weirs, and the construction of a second bar of rough stone on the floor of the barrage, so as to distribute the pressure of water by creating two drops instead of one, have been so far carried out, as successfully to hold up 3 metres of water during the seasons of Low Nile in 1885 and 1886, at a cost of less than £50,000, whilst much attention has been bestowed on the details of water distribution. A temporary dam has also been thrown across the Nile below Benha, and two others above Rosetta, so as to allow as little as possible of the precious water to escape into the sea. By these operations 90,000 acres of land have been brought under cultivation, and a tract has been supplied with water during the summer months which never received it before.

It is a fortunate circumstance that meanwhile Colonel Scott Moncrieff has not only been backed up to a great extent by the Egyptian Government, but has received the constant support of Nubar Pacha, who has shown a most enlightened desire to improve the country.

One able step he has recently enabled the Colonel to take is the partial abolition of the corvée, an army of unpaid and mixed labourers amounting to from eighty thousand to one hundred and twenty thousand, employed annually for half the year in clearing the canals of silt and doing all necessary earthwork. It was felt that the improvements would be of little avail so long as the scandal and burden of the corvée remained, which place such a cruel and oppressive load upon the poor, who had to find their own tools as well as give their personal labour. During the year 1885, as compared with 1884, the country was benefited by the labour of forty-eight thousand men for one hundred days released from tillage of the lands. A grant of £250,000 to spend on labour has this year been made in the face of all kinds of financial difficulties and opposition, and this has proved an immense boon to the country.

It is to be hoped that Colonel Scott Moncrieff, or some one or more of his able staff of officers, may furnish our Institution with a detailed and comprehensive account of their valuable labours, and of the means by which these results, so vitally affecting the interests of the Egyptian people, have been attained. They are, however, to be regarded only as an instalment of the larger benefits which are accruing from the prosecution of the complete scheme of contemplated works.

I take this opportunity of making brief reference to the success-

ful completion, during the current year, of two difficult and important undertakings nearer home.

I refer to the tunnel under the River Mersey, carried out under the direction of Sir James Brunlees and Sir Douglas Fox, inaugurated by his Royal Highness the Prince of Wales; and to the tunnel under the River Severn, which now forms (in the system of the Great Western Railway Company) the direct route for goods traffic, and will soon be opened for passengers, between South Wales and the Southern counties of England.

Notwithstanding the depression under which our commerce has been so long suffering, it is probable that at no previous period have engineering works of such surpassing interest and importance been projected, drawing so largely on the skill and resources of the engineer, as those which are now being executed under the direction of Sir John Fowler and Mr. Baker, the designers of the Forth Bridge, and of Mr. William Henry Barlow as regards that over the Tay. No bridge, I believe, at present existing, will compare with that which is to span the Forth, either in respect of the novel features of its constructive details or of its gigantic proportions. These structures will link into closer union the counties now separated by the estuaries of those rivers, besides shortening materially the distance between the metropolis and the western towns of Scotland.

I have to express my obligation to many gentlemen who have kindly favoured me with notes relating to various topics to which I have adverted in this Address, and I would especially acknowledge the courtesy of the Royal Commissioners representing our Colonies, the heads of the Locomotive Departments on our principal English and some of our Colonial Railways—the Secretaries of the Canadian Pacific and Bilbao River and Cantabrian Railways, and the Chief Engineer in Ottawa of the "Government Railways in operation,"—and Colonel Scott Moncrieff, for information kindly furnished me.

In conclusion, allow me to say that I enter on the honourable office to which you have elected me, with the earnest desire to promote in every way the interests of the Institution, and to discharge its duties to the best of my ability.

Moved by Sir Charles Hutton Gregory, seconded by Mr Abernethy, Past-President, and carried by acclamation, "That the best thanks of the members be tendered to Mr. Woods for his Address, and that he be requested to allow it to be printed in the Minutes of Proceedings."

APPEN

LEADING PARTICULARS of the MOST APPROVED TYPE OF LOCOMOTIVES

—	PASSENGER. London and North-Western Railway.	PASSENGER. Midland Railway.	PASSENGER. Great Northern Railway.	PASSENGER. North-Eastern Railway, Express.	PASSENGER. North-Eastern Railway, Ordinary.
I. ENGINE.	Compound 3 Cylinders.	Simple.	Simple.	Simple.	Simple.
Cylinders, outside or inside	2 out & 1 in	Inside	Outside	Inside	Inside
Do. dimensions: Diameter	H.P. 14 ins. L.P. 30 ins.	18 ins.	18 ins.	18 ins.	18 ins.
Do. dimensions: Stroke	H.P. 24 ins. L.P. 24 ins.	26 "	28 "	24 "	24 "
Weight of engine in working order	T. C. 42 10	T. C. Q. 42 14 3	T. C. 45 0	T. C. 42 11	T. C. 52 4
Maximum weight on any axle	15 0	15 0 0	17 10	16 4	17 7
Number of axles under engine	3	4	4	3	4
" driven axles	2	2	1	2	2
Diameter of driving-wheels	6 ft. 3 ins.	7 feet	8 ft. 1½ in.	7 feet	5 ft. 7 in.
Which end, if either, is carried on bogie-truck	Leading wheels fitted with radial axle-boxes	Front end	Leading end	..	Radial axles leading and trailing radial wheels
Diameter of bogie-wheels	3 ft. 6 ins.	3 ft. 6 ins.	3 ft. 11 ins.	None	3ft. 9 ins.
Description of valve-gear	Joy's	Link	Link	Stephenson	Joy's
Working-pressure, lbs. per sq. in.	175 lbs.	160 lbs.	140 lbs.	140 lbs.	140 lbs.
Area of firegrate	Square feet. 20·5	Square feet. 17·5	Square feet. 17¾	Square feet. 18·0	Square feet. 15·6
Heating surface: Firebox	159·1	110·0	109·0	110·5	98·0
Heating surface: Tubes	1,242·4	1,151·0	1,044·0	1,102·0	994·0
Total	1,401·5	1,261·0	1,153·0	1,212·5	1,092·0
Boiler shell, steel or iron	Steel	Steel & iron	Steel	Iron	Steel
Inner firebox, steel or copper	Copper	Copper	Copper	Copper	Copper
Tubes, copper, brass, or compound metal	67 copper 33 spelter	Copper	Copper	Brass	Brass
Tractive power per lb. per sq. in. pressure	..	100·28	93·04	92·57	116·06
II. TENDER.					Tank engine
Number of axles under	3	3	3	3	..
Weight in working order	T. C. 25 0	T. C. Q. 26 1 1	T. C. 36 0	T. C. 32 0	..
Weight of fuel carried	4 17	3 to 4 0 0	4 0	4 0	2 tons
Capacity of water-tanks	1,800 galls.	3,250 galls.	3,000 galls.	2,651 galls.	1,241 galls.
III. LOAD TAKEN.					
Limit of load allowed	No limit often 256½ tons	No limit	No limit	15 cars	18 cars
Steepest gradient traversed	1 in 75	1 in 100 1 in 90	1 in 200	1 in 96	1 in 40
Length of said gradient	4¼ miles	15 miles	12 miles	5 miles	3 miles
Gross load, exclusive of engine and tender, capable of being taken up steepest gradient	..	Tons. 156 up to 1 in 100 speed 35 miles per hour	..	15 cars	12 cars

DIX.

...USED by the PRINCIPAL ENGLISH RAILWAYS, 1886.

PASSENGER.						PASSENGER ENGINES BUILT in the UNITED STATES.	
North-Eastern Railway, Express Passenger.	Great Western Railway, Express.	London, Brighton, & South Coast Ry., Express.	Manchester, Sheffield, and Lincolnshire Railway.	Manchester, Sheffield, and Lincolnshire Railway.	Lancashire and Yorkshire Railway.	Chicago, Burlington, and Quincy Railroad.	Strong Express, Class 10, A², 20.
Compound 2 Cylinders.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.
Inside	Inside	Inside	Outside	Outside	Inside	Outside	Outside
H.P. 18 ins. L.P. 26 ins.	18 ins.	18¼ ins.	17 ins.	17½ ins.	17½ ins.	18 ins.	20 ins.
24 ins. each	24 „	26 „	26 „	26 „	26 „	24 „	24 „
T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C. Q. LB.	
42 10	35 0	38 14	41 1	40 11	41 15	36 19 1 4	..
16 10	15 8	14 10	15 0	17 0	14 13	12 3 1 6	..
3	3	3	4	3	4	4	6
2	1	2	2	1	2	2	2
6 ft. 8 ins.	7 feet	6 ft. 6 ins.	6 ft. 3 ins.	7 ft. 6 ins.	6 feet	5 ft. 9 ins.	7 feet
..	..	..	Leading end	Neither	Leading end	Front end	Bogie front end radial axle trailg: bogie, 3 ft. 2 ins.; trailg, 4 ft.
None	None	None	3 ft. 3 ins.	..	3 ft. 7¾ ins.	2 ft. 6 ins.	..
Joy's	Link	Link	Link	Link	Stephenson's Link	Link	Special
160 lbs.	140 lbs.	140 lbs.	140 lbs.	150 lbs.	140 lbs.	145 lbs.	160 lbs.
Square feet.	Square feet.	Square feet.	Square feet.	Square feet.	Square feet.	Square feet.	Square feet.
17·33	19·23	20·65	15·5	16·5	19·25	17·7	62·0
112·0	130·04	113·9	94·0	87·0	90·5	102·1	..
1,211·3	1,120·27	1,378·2	922·0	1,057·0	935·5	958·2	..
1,323·3	1,250·31	1,492·1	1,016·0	1,144·0	1,026·0	1,060·3	1,858·0
Steel	Steel	Iron	Iron	Iron	Iron	Steel	..
Copper	Copper	Copper	Copper	Copper	Copper	Steel	..
Brass	Steel	Steel	Copper	Copper	Iron	Charcoal iron	..
..	92·57	110·0	100·2	88·47	110·59	112·7	114·3
3	3	3	3	3	3	4	*Note.*—This engine is built to burn low quality anthracite or bituminous coal.
T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	
32 0	28 14	27 7	16 15	16 15	27 2	27 10	
4 0	2 10	2 0	2 10	2 10	3 0	6 10	
2,651 galls.	2,600 galls.	2,250 galls.	3,000 galls.	3,000 galls.	2,000 galls.	2,750 galls.	
18 cars	..	..	..	..	..	..	
1 in 96	..	..	1 in 97	1 in 97	1 in 27	..	
5 miles	..	..	8·58 miles	8·58 miles	1,056 miles	..	
18 cars	..	..	..	..	90 tons	..	

LEADING PARTICULARS of the MOST APPROVED TYPE OF LOCOMOTIVES USED

—	GOODS. London and North-Western Railway.	Midland Railway.	Great Northern Railway.	North-Eastern Railway, Heavy.	North-Eastern Railway, Heavy.
I. ENGINE.	Simple.	Simple.	Simple.	Simple.	Simple.
Cylinders outside or inside	Inside	Inside	Inside	Inside	Inside
Do. dimensions Diameter	17 ins.	18 ins.	19 ins.	18 ins.	18 ins.
Do. dimensions Stroke	24 „	26 „	28 „	24 „	24 „
Weight of engine in working order	T. C. 29 11	T. C. Q. 36 12 1	T. C. 40 0	T. C. 51 19	T. C. 37 0
Maximum weight on any axle	10 6	14 12 0	14 17	16 13	14 5
Number of axles under engine	3	3	3	4	3
„ driven axles	3	3	3	3	3
Diameter of driving-wheels	4 ft. 3 ins.	4 ft. 10½ ins.	5 ft. 1½ in.	5 feet	5 feet
Which end, if either, is carried on bogie-truck	..	..	..	Radial axle-box trailing	..
Diameter of bogie-wheels	None	None	None	3 ft. 9 ins. trailing	None
Description of valve-gear	Link	Link	Link	Joy's	Joy's
Working-pressure, lbs. per sq. in.	140 lbs.	140 lbs.	140 lbs.	140 lbs.	140 lbs.
Area of firegrate	Square feet. 17·1	Square feet. 17·5	Square feet. 18·0	Square feet. 17·23	Square feet. 17·23
Heating surface Firebox	94·6	110·0	112·0	110·0	110·0
Heating surface Tubes	980·0	1,151·0	1,240·0	1,026·12	1,026·12
Total	1,074·6	1,261·0	1,352·0	1,136·12	1,136·12
Boiler shell, steel or iron	Steel	B. Yorkshire iron	Iron	Steel	Steel
Inner firebox, steel or copper	Copper	Copper	Copper	Copper	Copper
Tubes, copper, brass, or compound metal	67 copper 33 spelter	Brass	Copper	Brass	Brass
Tractive power per lb. per sq. in. pressure	136	144	164·35	129·6	129·6
II. TENDER.				Tank engine	
Number of Axles under	3	3	3	..	3
Weight in working order	T. C. 25 0	T. C. Q. 29 12 1	T. C. 28 10	..	T. C. 32 0
Weight of fuel carried	4 17	3 0 0	4 0	2 tons	4 0
Capacity of water-tanks	1,800 galls.	2,200 galls.	2,800 galls.	1,241 galls.	2,651 galls.
III. LOAD TAKEN.					
Limit of load allowed	35 wagons	No limit	400 tons	400 tons	400 tons
Steepest gradient traversed	1 in 77	1 in 100	1 in 200	1 in 60	1 in 107
Length of said gradient	3½ miles	15 miles	12 miles	10 miles	4 miles
Gross load, exclusive of engine and tender, capable of being taken up steepest gradient	..	Tons. 360 up to 1 in 100, speed 15 miles per hour	..	250 tons	360 tons

by the Principal English Railways, 1886.					Goods Engines built in the United States.		
GOODS.							
North-Eastern Railway, Heavy.	Great Western Railway, Heavy.	London, Brighton, & South Coast Ry., Heavy.	Manchester, Sheffield, and Lincolnshire Railway.	Lancashire and Yorkshire Railway.	Central Pacific Railroad.	Dom Pedro II. Railway, Brazil.	Southern Pacific Railroad of New Mexico.
Compound 2 Cylinders.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.
Inside	Inside	Inside	Inside	Inside	Outside	Outside	Outside
H.P. 18 ins. L.P. 26 ins.	17 ins.	18½ ins.	17½ ins.	17½ ins.	21 ins.	22 ins.	20 ins.
24 ins. each	26 "	26 "	26 "	26 "	36 "	26 "	26 "
T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.
37 0	36 18	40 7	40 0	37 5	77 0	64 6	51 7
14 5	12 6	14 0	16 19	12 15	65 0	57 3	44 13
3	3	3	3	3	7	6	5
3	3	3	3	3	5	5	4
5 feet	5 feet	5 feet	4 ft. 9 ins.	4 ft. 6 ins.	4 ft. 9 ins.	3 ft. 9 ins.	3 ft. 6 ins.
..	..	..	..	..	Leading end	Single pony truck at leading end	..
None	None	None	None	None	2 ft. 2 ins.	2 ft. 4 ins.	..
Joy's	Link	Link	Link	Stephenson's Link	A. J. Stevens	..	..
160 lbs.	140 lbs.	140 lbs.	130 lbs.	140 lbs.	..	..	..
Square feet. 17·23	Square feet. 15·2	Square feet. 20·95	Square feet. 18·25	Square feet. 19·50	..	Square feet. 33·0	Square feet. ..
110·0	103·29	101·0	87·0	90·5	..	160·0	153·0
1,026·12	1,053·8	1,312·0	1,141·0	935·5	..	1,783·0	1,223·84
1,136·12	1,157·09	1,413·0	1,228·0	1,026·0	..	1,943·0	..
Steel	Steel	Iron	Iron	Iron	..	Iron	..
Copper	Copper	Copper	Copper	Copper	..	..	..
Brass	Steel	Steel	Copper	Iron	..	..	..
..	125·23	143·02	139·69	147·45	278·6	279·6	247·6
3	3	3	3	3	*Note.*—The 65 tons are distributed over 5 pairs of driving-wheels.	*Note.*—The 57 tons 3 cwt. are distributed over 5 pairs of driving wheels.	*Note.*—The 44 tons 13 cwt. are distributed over 4 pairs of driving wheels.
T. C.	T. C.	T. C.	T. C.	T. C.			
32 0	28 8	28 8	16 15	27 2			
4 0	2 10	2 0	2 10	3 0			
2,651 galls.	2,500 galls.	2,550 galls.	3,000 galls.	2,000 galls.			
450 tons	..	..	350 tons	480 tons			
1 in 107	..	..	1 in 97	1 in 27			
4 miles	..	..	858 yards	1,056 yards			
400 tons	..	..	395 tons	120 tons			

16 November, 1886.

EDWARD WOODS, President, in the Chair.

The Secretary read the notice convening the meeting as follows:—

NOTICE IS HEREBY GIVEN that a Special General Meeting of the Corporate Members of The Institution of Civil Engineers will be held at 25, Great George Street, Westminster, on Tuesday, the 16th day of November, 1886, at half-past four o'clock, for the purpose of considering the proposed Supplemental Charter (a print of which is enclosed), to extend the powers for holding Lands, &c., from the yearly value of £1,000, as authorised by the original Charter, to £10,000, and, if approved, directing the presentation of a Petition (a print of which is also enclosed) to Her Most Gracious Majesty, praying Her to grant to the Institution the said Royal Charter.

Dated this 6th day of November, 1886.

JAMES FORREST,

Secretary.

The following draft Supplemental Charter and Petition to H.M. the Queen in Council, together with accompanying circular, were taken as read.

Victoria, BY THE GRACE OF GOD OF THE UNITED KINGDOM OF GREAT BRITAIN AND IRELAND QUEEN DEFENDER OF THE FAITH.

To all to whom these presents shall come greeting—

Whereas the body politic and corporate of THE INSTITUTION OF CIVIL ENGINEERS was incorporated under or by virtue of a certain Charter or Letters Patent bearing date at Westminster the 3rd day of June in the ninth year of the reign of King George the Fourth and the said Institution is now regulated and governed by and according to the provisions of the said Charter or Letters Patent and also by or according to certain by-laws and regulations made by the said Institution AND WHEREAS by the said Charter or Letters Patent the said Institution has full power and authority *inter alia* to be able and capable in the law notwithstanding the Statutes of Mortmain to take purchase possess hold and enjoy to them and their successors a Hall and any messuages lands tenements or hereditaments whatsoever the yearly value of which including the site of the said Hall shall not exceed in the whole the sum of £1,000 computing the same respectively at the rack rent which might have been had or gotten for the same respectively at the time of the purchase or acquisition

thereof AND WHEREAS the said Institution presented their humble Petition to us alleging *inter alia* as follows:—

"At the time the said Charter was granted the number of members of all classes was 156 and the income for that year was £446 16*s*. The number of members of all classes on the 3rd of June 1886 was 5174 and the total annual receipts of the said Institution for the past year were £19945.

"The premises now occupied by the Institution are situate at No. 25 Great George Street Westminster and the Institution entered into possession of them at Christmas 1839 The said premises have become and are totally inadequate for the accommodation now required It is therefore in contemplation to acquire additional property adjoining the said premises for the extension thereof The powers of the Charter as to holding land have become exhausted and the Institution are therefore desirous that the yearly value of the property to be held by them should be extended to the sum of £10000 at the time of purchase."

Therefore the Petitioners most humbly supplicated Us to grant Our Royal Charter enlarging the Charter of Incorporation for the purpose of empowering the Institution to purchase and hold messuages lands tenements and hereditaments of a yearly value not exceeding at the time of purchase the sum of £10000.

NOW KNOW YE THAT WE taking the premisses into Our Royal consideration of Our especial Grace certain knowledge and mere motion have granted constituted and appointed and by these presents for Us Our heirs and successors do grant constitute and appoint as follows that is to say:—

1. That the powers of the Institution of Civil Engineers notwithstanding the Statutes of Mortmain to take purchase possess hold and enjoy to them and their successors a Hall and any messuages tenements or hereditaments whatsoever the yearly value whereof was not to exceed the yearly value in the said Charter mentioned and the powers unto all and every person and persons bodies politic and corporate (otherwise competent) to grant sell alien and convey in Mortmain unto and to the use of the said Society and their successors any messuages lands tenements or hereditaments not exceeding the yearly value therein mentioned shall be and are hereby extended so that the yearly value of the Hall messuages lands tenements and hereditaments acquired or to be acquired under the said Charter and this Charter shall not exceed £10000 computing the same respectively at the rack rent which might have been had or gotten for the same respectively at the time of the purchase or acquisition thereof.

2. And WE do hereby for Us Our heirs and successors grant and declare that these Our Letters Patent or the enrolment or exemplification thereof shall be in all things valid and effectual in law according to the true intent and meaning of the same and shall be construed and adjudged in the most favourable and beneficial sense for the best advantage of the said Institution as well as in

Our Courts as elsewhere notwithstanding any recital misrecital uncertainty or imperfection in these Our Letters Patent.

In witness whereof WE have caused these Our Letters to be made Patent Witness Ourself at Our Palace of this day of in the fiftieth year of Our Reign (A.D. 1886).

By Her Majesty's command.

TO THE

QUEEN'S MOST EXCELLENT MAJESTY IN COUNCIL.

The Humble Petition of THE INSTITUTION OF CIVIL ENGINEERS of which EDWARD WOODS Esquire is the President, GEORGE BARCLAY BRUCE Esquire, SIR JOHN COODE K.C.M.G., GEORGE BERKLEY Esquire, and HARRISON HAYTER Esquire are the Vice-Presidents; WILLIAM ANDERSON Esquire, BENJAMIN BAKER Esquire, JOHN WOLFE BARRY Esquire, SIR HENRY BESSEMER F.R.S., EDWARD ALFRED COWPER Esquire, SIR JAMES NICHOLAS DOUGLASS, SIR CHARLES DOUGLAS FOX, ALFRED GILES Esquire M.P., JAMES MANSERGH Esquire, WILLIAM HENRY PREECE Esquire F.R.S., SIR ROBERT RAWLINSON C.B., SIR EDWARD JAMES REED K.C.B., F.R.S., M.P., FRANCIS CROUGHTON STILEMAN Esquire, SIR WILLIAM THOMSON F.R.SS. L. & E., and SIR JOSEPH WHITWORTH Bart., F.R.S., are the Members of the Council; and SIR JOHN HAWKSHAW F.R.S., SIR JOHN FOWLER K.C.M.G., SIR CHARLES HUTTON GREGORY K.C.M.G., THOMAS HAWKSLEY Esquire F.R.S., THOMAS ELLIOT HARRISON Esquire, GEORGE ROBERT STEPHENSON Esquire, JOHN FREDERICK LA TROBE BATEMAN Esquire F.R.SS. L. & E., WILLIAM HENRY BARLOW Esquire F.R.S., JAMES ABERNETHY Esquire F.R.S.E., SIR WILLIAM GEORGE ARMSTRONG C.B., LL.D., D.C.L., F.R.S., SIR JAMES BRUNLEES F.R.S.E., SIR JOSEPH WILLIAM BAZALGETTE C.B., and SIR FREDERICK JOSEPH BRAMWELL D.C.L., F.R.S., are Past Presidents:

Humbly sheweth as follows:—

On the 3rd of June 1828 the said Institution was incorporated by a Charter granted by His Majesty King George the Fourth in which it was recited that a Society having been formed for the general advancement of mechanical science and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a Civil Engineer being the art of directing the great sources of power in nature for the use and convenience of man as the means of production and of traffic in states both for external and internal trade as applied in the construction of roads bridges aqueducts canals river navigation and docks for internal intercourse and exchange and in the construction of ports harbours moles breakwaters and lighthouses and in the art of navigation by artificial power for the purposes of commerce and in the construction and adaptation of machinery and in the drainage of cities and towns by such Charter the said Society and its future Members was incorporated by the name of "The Institution of Civil Engineers" with perpetual succession and full power and authority *inter alia* to be able and capable in the law (notwithstanding the Statutes of Mortmain) to take purchase possess hold and enjoy to them and their successors a Hall and any messuages lands tenements or hereditaments whatsoever the yearly value of which including the site of the said Hall should

not exceed in the whole the sum of £1000 computing the same respectively at the rack rent which might have been had or gotten for the same respectively at the time of the purchase or acquisition thereof and such Charter also granted special license and authority unto all and every person and persons bodies politic and corporate (otherwise competent) to grant sell alien and convey in mortmain unto and to the use of the said Society and their successors any messuages lands tenements or hereditaments not exceeding such annual value as aforesaid.

At the time the said Charter was granted the number of members of all classes was 156 and the income for that year was £446 16s.

The number of members of all classes on the 3rd of June 1886 was 5174 and the total annual receipts of the said Institution for the past year was £19945.

It is provided by the By-Laws of the said Institution that it shall consist of different classes viz. Honorary Members Members Associate Members Associates and Students. The following are the respective number of each of these classes viz.:—

Honorary Members	20
Members	1558
Associate Members	2187
Associates	499
Students	910
	5174

The Honorary Members are:—

His Royal Highness Albert Edward Prince of Wales K.G., K.T., K.P., G.C.B., G.C.S.I., &c.
His Royal Highness the Duke of Edinburgh K.G., K.T., K.P., G.C.S.I., G.C.M.G., &c.
His Royal Highness the Duke of Connaught K.G., K.T., K.P., G.C.S.I., G.C.M.G., &c.
His Royal Highness the Duke of Cambridge K.G., K.P.G., C.B., G.C.M.G., &c.
His Majesty the King of the Belgians.
His Majesty the Emperor of Brazil F.R.S.
His Majesty the King of Portugal.
His Grace the Duke of Devonshire K.G., D.C.L., F.R.S.
His Grace the Duke of Sutherland K.G., F.R.S.
Earl Granville K.G., F.R.S.
Viscount Eversley G.C.B., D.C.L.
Lord Bramwell F.R.S.
Sir Frederick Augustus Abel C.B., D.C.L., F.R.S.
Sir George Biddell Airy K.C.B., M.A., D.C.L., F.R.SS. L. & E.
Jean Charles Adolphe Alphand.
Rudolph Julius Emanuel Clausius.
Sir William Robert Grove M.A., D.C.L., LL.D., F.R.S.
Sir Ferdinand de Lesseps G.C.S.I., LL.D.
John Percy M.D., F.R.S.
John Tyndall LL.D., F.R.S.

The premises now occupied by the Institution are situate at No. 25 Great George Street Westminster and the Institution entered into possession of them at Christmas 1839. Alterations have from time to time been made in order to provide the additional accommodation required and in the year 1868 the

building was enlarged by the addition of the back part of No. 24 Great George Street.

There is no limitation to the number of members the only limitation being in their qualification. The said premises have become and are totally inadequate for the accommodation now required.

It is therefore in contemplation to acquire additional property adjoining the Institution for the extension of its premises. The powers of the Charter as to holding land have become exhausted and the Institution are therefore desirous that the yearly value of the property to be held by them should be extended to the sum of £10000 at the time of purchase.

Your Petitioners therefore most humbly supplicate Your Majesty to grant Your Royal Charter to enlarge the Charter of Incorporation so as to empower the Institution to purchase acquire and hold messuages lands tenements and hereditaments of the yearly value not exceeding at the time of purchase or acquisition the sum of £10000.

THE INSTITUTION OF CIVIL ENGINEERS.
Established 1818. Incorporated by Royal Charter 1828.
25, Great George Street, Westminster, S.W.
[Telegrams, "Institution, London." Telephone, "3051."]
6th November, 1886.

DEAR SIR,

In forwarding the accompanying notice for a Special General Meeting to approve the proposed Supplemental Charter, I am directed to explain that for some time past, the Library and Office accommodation have been insufficient for the increasing business of the Institution, and as the powers granted by the original Charter as to the annual value of lands which may be legally held by the Institution have been exhausted, it has become necessary to obtain enlarged powers in order to acquire additional premises. Hence the contemplated extension of the Charter, and the proposed Meeting to approve it.

I am,
Your obedient Servant,
JAMES FORREST,
Secretary.

Mr. E. Woods, President, having explained the necessity that had arisen for an extension of the powers conferred by the Original Charter, concluded by moving—

"That the proposed Supplemental Charter be and is hereby approved, and that the Petition to Her Most Gracious Majesty be sealed and presented accordingly."

Mr. G. B. Bruce, the senior Vice-President, having seconded the motion, the Resolution was formally put, and declared to be carried unanimously.

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16 November, 1886.

EDWARD WOODS, President,
in the Chair.

(*Paper No. 2198.*)

"Concrete-Work under Water."

By Walter Robert Kinipple, M. Inst. C.E.

In 1856, the Author commenced a series of experiments, which were extended over several years, with the object of finding out some means by which Portland cement might be employed with equal success below water as above, in the construction of monolithic works without the aid of heavy and costly plant, to which reference was made in the discussion on Mr. Grant's Paper on the strength of cement in 1865.[1] The Author thinks that the practical results gathered from his experiments, and from depositing concrete under water in various important works which he has carried out since 1856, may assist in determining the best method of employing Portland cement under water so as to obtain thoroughly reliable work at a moderate cost. He considers that the present methods of constructing submarine works with Portland cement do not accomplish these objects, owing to the cost of the excessive proportion of cement required for concrete deposited *in situ* when freshly mixed, or the expensive plant needed for large concrete blocks.

In his early experiments in 1856, the Author's attention was attracted to the property possessed by partially-set concrete of uniting under water into a solid mass, though passed through the water in lumps sufficiently set to resist a current of water and some action of the sea. Since then he has constantly used this plastic concrete, as he has termed it, for concrete-work under water, both in large and in small works.

The portion of the south-west pier quay-wall at the Garvel

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[1] Minutes of Proceedings Inst. C.E., vol. xxv. p. 125.

Basin, Greenock, below low-water, was formed of plastic concrete deposited behind a facing of greenheart piles (Plate 1, Fig. 1). The concrete next the piling, for a thickness of 3 feet, was composed of 2 parts of cement to 7 of sand and ballast, and the remainder of 1 of cement to 6 of sand and ballast; the former was left to set for nearly three hours, and the latter for nearly five hours before being deposited; but a longer time was allowed for slow-setting, and a shorter time for quick-setting cement. The condition also of the atmosphere, and the quantity of water used in mixing, affected the rate of setting. The best results were obtained when the ingredients were mixed with the smallest possible quantity of water, and then at once rammed into the boxes, and deposited under water as soon as the concrete had set to the consistency of stiff clay. If the concrete was deposited too soon after mixture, a loss of cement resulted, and if left to set till nearly hard, it was unfit to unite with the mass of the concrete after deposition. Where there are currents or much disturbance of the water by waves, it is advisable to add a small quantity of quick-setting cement to the plastic concrete just before deposition, as this stiffens the concrete considerably, and materially helps it to resist currents or wave-action, whilst not interfering with its property of setting and uniting with the mass of concrete previously deposited. The work was very satisfactorily executed in depths of from 8 to 38 feet below high-water, at a cost of 30*s.* per cubic yard for the front concrete, and 21*s.* for the back.

At the entrance to the West Harbour, and along the face of the Steamboat Quay, Greenock, a concrete wall, 1,150 feet long and from 3 to 17 feet thick, was formed between two rows of sheet-piling, in depths of from 15 to 30 feet below high-water, and raised 6 feet above high-water. The work was carried on at all states of the tide, with plastic concrete composed of 1 part of cement to 6 parts of sand and ballast, at a cost of 15*s.* per cubic yard. The work between high- and low-water could be daily inspected at low-water, when it was seen to be perfectly sound; and the Author considers that this was entirely due to the care taken in letting the concrete set partially before being deposited. The divers reported that the part of the wall under low-water was as sound as that above. A bed of 6 to 1 concrete, 220 feet long, 26 feet wide, and 4½ feet thick, was also deposited at the entrance to the West Harbour, at a depth of 20 feet below low-water, as a foundation for the roller-path of the movable bridge spanning the entrance. It proved thoroughly sound, and cost 18*s.* per cubic yard. In both these works, the concrete was rammed thoroughly

into the boxes and allowed to set for two or three hours before being deposited, as at the Garvel Park Dock.

Experiments made at the Garvel Park dock works by Mr. Daniel Macalister, Assoc. M. Inst. C.E., show that $3\frac{1}{2}$ to 1 concrete, after setting out of water for eighteen hours, and then rammed into moulds, will form a monolithic mass when afterwards placed in water; but that the strength of this mass will very much depend upon the time allowed for setting before deposition. If only eight hours elapse between mixing and deposition, there is practically no reduction in strength; but with a longer interval, the strength is gradually reduced, until at about eighteen hours it is little more than one-half.

At the Girvan Harbour extension works in Ayrshire, designed and carried out by the Author, a pier, groyne, and quay-wall were constructed of concrete deposited in a plastic state (Plate 1, Figs. 2, 3, 4, and 5). The face-work of the pier above low-water was at first constructed within temporary sheet-piling, which, even when lined with grooved and tongued boarding, proved unsatisfactory; and subsequently a facing of dove-tailed concrete blocks, 21 inches long and 12 inches deep, bonding into the concrete hearting, was adopted with success where the wash was very great (Plate 1, Figs. 6 and 7). As the blocks only weighed about 180 lbs. each in air, and 80 lbs. in water, they were easily handled without a crane. These blocks extended from low-water level to the underside of the coping at 6 feet above high-water (Plate 1, Fig. 2); they were made of 1 part of Portland cement to 4 parts of sand and fine gravel; and their exposed faces and arrises were rendered with a $\frac{1}{2}$-inch coat of 1 to 1 Portland cement mortar. Small semi-dovetailed grooves all round the outer arrises of each block made (when the blocks were laid in position) complete dovetailed grooves with the adjacent blocks, which, as each course was laid, were filled up with clay or quick-setting cement, making the blocks into a water-tight dam, behind which the plastic concrete was deposited to within 6 inches of their tops. Thick cement grout was then poured down the circular holes in the centres and end joints of the blocks, which spread over the hollowed-out beds, and flowed into the hearting, firmly cementing it to the facing blocks.

The pier was constructed by enclosing lengths of 15 feet by 3 feet high with these blocks, and filling these lengths with plastic concrete. The surface of the concrete in these compartments was effectively protected, at the close of each tide or day's work, by a covering of closely-packed pitching, grouted with fine

F 2

concrete, and finished off with a grout composed of 3 parts of Portland cement to 1 part of a quick-setting cement.

In the construction of the groyne (Plate 1, Figs. 3 and 4), a movable shield was used, formed of wrought-iron plates and angle-irons, with two sides and one closed end, or nose, and one open end. It was about 40 feet long, and extended from the foundation, at 1 foot above low-water, to the coping at 3 feet above high-water; it fitted closely to the groyne, and enclosed about 33 feet of the newly-formed work, leaving a space, about 7 feet long, between the nose of the shield and the end of the groyne, in which the plastic concrete was deposited almost independently of the state of the weather. When the shield was in good order, 120 lineal feet of groyne were completed in a fortnight. This shield was rendered useless during a severe gale, having been constructed by the contractor rather as an experiment than to withstand heavy seas. The Author had suggested the shield to the contractor, and was so well satisfied with its capability during the construction of the groyne that he subsequently designed a large one adapted for the construction of a breakwater (Plate 1, Figs. 16 and 17). The remainder of the groyne was carried out more slowly, partly by means of a facing of close piling, and partly by dove-tailed facing blocks. The average cost of the concrete in the pier and groyne, including the facing-blocks, was 13*s*. 6*d*. per cubic yard.

At Wick, the Author, in rebuilding the head of the South Pier, which had been destroyed during the storm of February 17, 1880, formed blocks of 60 to 140 tons in position in sailcloth, which protected them from the waves till the mass was firmly set. A piece of sailcloth, of sufficient size to enclose the block, was turned up to form a sort of bag, in which plastic concrete was deposited; and when full, the edges were folded over, and kept down with heavy iron weights till the concrete had set. The whole of the rubble base of the South Pier was encased by this means in a mass of 6 to 1 concrete, and has resisted the gales of several winters without the slightest damage. The concrete cost about 18*s*. per cubic yard. On one occasion, a 60-ton block formed in position on the end of the pier, 2 feet above low-water, resisted a most severe storm within twenty hours after its completion, although the sailcloth was wholly removed by the waves.

At the Quebec harbour works, the Author formed the quay-walls of cribwork, filled with plastic concrete (Plate 1, Fig. 8). The conditions under which works are carried out at Quebec differ considerably from those of this country, for the working season is

confined to about half the year, and all plant or temporary works must be removed at its close, as only substantial works can resist the breaking-up of the ice in spring. The cribs were constructed during the winter of 1878 and the following spring, and between May and November, 1879, were floated into position, and sunk on the tops of bearing-piles, 24 feet below low-water. The cribs, extending over a length of 1,250 feet, were each 40 feet long, 33 feet wide at the base and 23 feet at the top, and 27 feet high; and their front cells were filled from bottom to top with plastic concrete in the following proportions, namely, the front 2 feet of concrete in the proportion of 4 to 1, and the remainder 8 to 1, and costing respectively 26*s.* and 19*s.* 9*d.* per cubic yard. The floating out of the cribs forming the entire length of 1,250 feet of work, dredging out the trench, sinking cribs into position on the bearing-piles, filling up the front cells with concrete, and the back cells with clay and stones, occupied about five months, being at the rate of 1 lineal foot of complete work up to 3 feet below low-water per working hour.

Plastic concrete was used by Mr. W. Smith, M. Inst. C.E., at Aberdeen Harbour, on the Author's advice, for the substructure of a new quay-wall founded 24 feet below high-water spring-tides, having a height of 14 feet, and a thickness of 10 feet, which was increased to 12 feet at the base by a sloping toe in front (Plate 1, Fig. 9). Three complete frames, formed of timber strengthened with angle-irons, and placed 10 feet apart, were first filled with concrete; and three intermediate frames, with only back and front, were subsequently filled (Plate 1, Fig. 10). The concrete in the first compartment was composed of 1 part of Portland cement, 3 parts of coarse sand, and 4 of granite chips; and in the other compartments, for one-third of the height, of 1 part of Portland cement, 2 parts of sand, 3 of granite chips; and for the remainder, of 1 part of Portland cement, and 7 parts of sand and chips, with about 12 tons of rubble in each compartment. The concrete for the first compartment was allowed to set twelve hours after mixture before being deposited in the frames, the cement being old and slow-setting. The concrete was found perfectly hard on the removal of the framing after three weeks. In constructing another quay-wall somewhat similarly, Mr. Smith allowed only from one to two hours before depositing concrete made with quick-setting cement. Both these walls were carried on at all states of the tide.

Some experiments were carried out by Mr. Smith at Aberdeen, and Mr. H. G. H. Spencer, Assoc. M. Inst. C.E., at St. Heliers, Jersey, at the Author's suggestion, under the belief that the

system of grouting, adopted by him for joining the face blocks at Girvan, might be advantageously extended. At Aberdeen, a timber box, 6½ feet long, 1 foot wide, and 4 feet deep, was filled with round smooth stones of basalt and whinstone, from 1 to 4 inches in diameter, and was lowered to the bottom of the tidal harbour in a depth of 18 feet at high-water spring-tides. At high-water, a thick grout of 4 parts of Portland to 1 part of Sheppey cement was poured down a wrought-iron pipe, 3½ inches in diameter, reaching down 12 inches into the box, and rising a few feet above the water-level; and this grout filled the interstices between the stones. After twelve days, the box was lifted out of the water by means of the pipe, which had become firmly cemented into the concrete; and on removing the sides of the box, the concrete was found to have a smooth surface, and to be perfectly solid throughout. At Jersey, two experiments were made. First a box, about 6 feet cube, was filled with shingle, and a 1½-inch gas-pipe was inserted 18 inches into it, and when the tide had risen 20 feet above the box, thick neat cement grout was poured down the pipe; on opening the box afterwards, its contents were found united into a solid mass, with the grain of the rough-sawn timber of the box imprinted upon the surface of the concrete, so completely had the grout filled up all the interstices of the box. Secondly, a box, 2 feet cube, filled with shingle, was suspended 60 feet under water in the strong tide-way of the Little Roads. A thick grout of Portland cement was poured through a tube reaching down to the box, which united with the shingle into a single concrete block. The block was not so perfect as in the first experiment, owing to the bottom zinc tubing being crushed by the weight of the iron tubing above, which allowed the grout to escape; but the failure was only partial, for one-half of the block was thoroughly solid and had sharp arrises. These experiments confirm those made by the Author in 1858, in proving the feasibility of cementing shingle in foundations at great depths, grouting up fissures, and repairing works undermined by the sea or scour.

Portland cement grout was successfully used by the Author, in 1882, in stopping considerable leakages at No. 1 Graving Dock in the West Harbour, Greenock, which had given so much trouble for some years as to lead to proposals for reconstructing or removing the dock. Bore-holes were made, 1 foot to 2 feet apart, through the masonry behind the heel-posts into the sand for several feet below the foundations, and also through the inner and outer aprons near the pointing-sill, on which latter holes stand-pipes were set up. A thick grout of neat Portland cement was poured down these

holes, which permeated the various fissures and open joints to a distance, in some cases, of 18 feet from the bore-holes, virtually joining the bore-holes together, and thereby forming a water-tight sheeting of cement; and about 5 tons of cement were used in grouting up the holes. The grout was only poured down the stand-pipes when the water was at the same level inside and outside the dock; and it carried down the water-level inside the pipes 6 feet below the water-level outside. Before these operations were carried out, an 18-inch pump was constantly working to keep down the leakage; whereas subsequently, only one hour's pumping was required in forty hours.

Grouting might be extensively used in forming the hearting of piers and quay-walls by packing small grooved blocks (Plate 1, Fig. 11), composed of concrete consisting of 12 parts of gravel to 1 part of cement, behind a facing of blocks like those at Girvan pier (Plate 1, Figs. 6 and 7), and then grouting them together into a solid mass by neat cement poured down through tubes from the surface of the water. Large hearting-blocks deposited by a crane might be economically substituted for hand-blocks in large works; for the saving in cement and diving work would more than compensate for the cost of the plant.

Some of the various methods of constructing monolithic piers in the sea with plastic concrete, proposed by the Author, are shown in Plate 1, Figs. 12 to 17. One system of construction is by means merely of sand-bags and sailcloth. A trench must first be dredged for a foundation, and its irregularities filled up with plastic concrete, forming a fairly level surface upon which concrete blocks can be cast in position. The facing blocks are first cast in a mould, formed by piled-up sand-bags lined with sailcloth, whose sides and ends are then folded over the concrete and weighted down, protecting it completely from the action of the sea; as soon as the block is sufficiently hard, the weights and sand-bags are removed, and the loose sailcloth is cut away. The adjoining blocks are then formed in a similar way, the side of the previous block serving for one side of the mould instead of a pile of bags. The blocks can be cast of any size and shape; but there is little need to make them break joint, as being concreted together they form a monolithic mass, thus differing from the ordinary dry block and bag systems which depend upon the weight of each block and the proper breaking of joint throughout the work. The facing above low-water may consist of small dove-tailed blocks, similar to those used at Girvan pier, or of various other forms of facing; and the hearting between the facing blocks can be formed

by concrete blocks cast in position, like the lower portion of the pier. By the above method, a monolithic pier or breakwater can be formed with the minimum amount of plant. The system is well suited for constructing works in exposed localities above low-water level; and even though its cost below low-water would be increased by diving work, it might be advantageously adopted where expenditure on special plant is unadvisable.

In sheltered situations, and during calm periods, the sailcloth and bags of sand may be dispensed with, and the plastic concrete hearting deposited behind the facing blocks without any protection. The facing blocks may be similar to those of Girvan pier; or much larger blocks might be deposited by cranes; or a facing of concrete blocks cast in position might be adopted. The plastic concrete is deposited in a series of cells formed by cross walls of blocks; and by keeping the outer walls above the level of the hearting, the wave-disturbance over the surface of the hearting is reduced.

Another simple inexpensive method of constructing breakwaters without special plant is shown in Plate 1, Figs. 12 and 13. Mounds of plastic concrete are deposited in two trenches excavated along the lines of each face of the breakwater; and round wrought-iron piles are driven into the soft concrete, along the top of each mound, through the eyes of distance-bars, and their heads are held in position longitudinally by similar bars, and transversely by wire ropes anchored out on each side of the breakwater, and connecting them across the breakwater, and provided with adjusting shackles to keep the piles in line (Plate 1, Fig. 12). Oak planking is secured to the piles at the back by loop bolts, so that the planks, fastened in groups of two or three, are free to slide down (Plate 1, Fig. 13). Openings in the joints of the planking are covered with sailcloth before the fine plastic concrete is placed against the faces; and the work is advanced in steps by help of partition walls at intervals, formed of plastic blocks or sand-bags; and sailcloth with weights may be used to cover up each day's work.

Concrete caissons, forming a modification of the system of crib-work blocks adopted by the Author at Quebec, might be extensively used in constructing considerable lengths of breakwater at a time (Plate 1, Figs. 14 and 15). The caissons may be built on launching-ways on shore, and, when thoroughly seasoned, may be towed into position in favourable weather, and sunk by admitting water, either by means of pipes (Plate 1, Fig. 14), or by pumping over the side. A foundation for the caisson may be formed by excavating a trench and filling it up level with concrete, or with

gravel, subsequently grouted with cement poured down stand-pipes through the caissons. Bearing surfaces are formed on the bottom of the caissons, either of concrete (Plate 1, Fig. 14), or of timber bedded into the concrete. On sinking the caissons, the projecting bearing surfaces rest upon the prepared foundation; and the intervening spaces are afterwards filled up solid with Portland cement grout, poured down through stand-pipes. At the junction of two caissons, dove-tailed grooves filled with oakum, tallow, clay, or quick-setting cement, serve to form water-tight partitions, and prevent any cement from washing out of the joints. The interior of the caissons may be filled with plastic concrete, and large stones, which, when raised nearly to the top of the caisson, can be protected for a time, if necessary, by weighted sailcloth, or with a paving of small grooved blocks grouted with quick-setting cement. The caissons may either be made strong enough to be floated out to withstand the waves before being filled with the hearting; or they may be strengthened by angle-iron framing built into the concrete, as shown by Plate 1, Figs. 14 and 15. The strengthening was carried much further in caissons designed for a proposed extensive breakwater, where as much buoyancy as possible was desired. In this case each caisson consisted of a framework of angle-iron having a facing of concrete; in fact, an iron caisson plated with concrete instead of iron was proposed, thus combining considerable strength and buoyancy. The caissons were to be constructed on launching-ways down which each was to be launched into a large circular barge or pontoon, and, in suitable weather, conveyed to the site of the works, sunk, and filled up with plastic concrete and large stones. A temporary wooden platform, secured to the top of each caisson, prevented water getting into the caisson when launched from the barge near the site of the works. The platform is provided with manholes, through which the concrete is lowered into the caisson; and it is not removed, to serve for another caisson, till the concrete hearting of the caisson has set hard.

A modification of the above system, specially applicable to great depths of water, consists of a base, or mound, formed of a facing of large concrete bags with a hearting of plastic concrete, raised to a suitable level below low-water, on which a concrete caisson is placed and filled up with concrete; or a rubble mound might be formed, kept below the disturbing action of the waves, as a foundation for the concrete caisson.

A system of constructing breakwaters by means of a travelling shield or casing, similar to that used at Girvan, but on a much

larger scale, is shown in Plate 1, Figs. 16 and 17, inside which work may be carried on in the most stormy weather. A level concrete base is first formed for the travelling casing, into which short iron stakes or bearing-piles are driven at convenient intervals; transverse sleepers are placed on the top of these stakes, and kept in position by plastic concrete surrounding them. On these sleepers, rolled beams or other guides are laid down, along which the casing moves, either on rollers or on timber bearings. The cellular casing, formed to the cross section of the breakwater, is provided with hinged interior side linings, moved by screws to and from the face of the newly-finished work, and also with a movable end, to which hydraulic rams are attached by which the whole casing, except the movable end, is pushed forward. The casing encloses a considerable portion of the completed breakwater, thus protecting the more recent work, and steadying the casing during stormy weather. The work is constructed in lengths (Plate 1, Fig. 16); and for forming a fresh length, the hinged sides are moved back by the adjusting screws from the face of the work, the casing is pushed forward the required distance by the hydraulic rams, which, with the movable end, are then drawn back close up to the fixed diaphragm, and the hinged sides are brought tight up against the last finished length and the movable end. Water-tight joints are then formed between the hinged sides and the concrete, by india-rubber or leathern pipes let into grooves and swelled out by water under pressure so as to fill up the irregularities in the face of the work. Sailcloth may be used along the bottom of the hinged sides to protect the newly-deposited concrete from any wash. Plastic concrete can then be deposited in the space between the casing and the end of the work, where the water is so still in the roughest weather that the work can be carried on continuously. Two small tunnels could be formed in the breakwater, along which self-emptying skips could be conveyed and brought back by an endless rope, depositing their contents in the space at the end, in which the water rises and falls with the tide outside by means of sluices (Plate 1, Fig. 17). A crane at the end of the casing, fitted with a dredging bucket, serves to excavate the foundation trench in front, and may also assist in depositing the concrete. The crane can be lowered on to the top of the casing when not in use (Plate 1, Fig. 16). The casing can be floated into and out of position, and be ballasted in place by filling up the whole of the cells of the structure with water; or pig-iron may be used, to give it greater stability in rough weather.

Though the proposed casing described above constitutes expen-

sive plant, it might prove very economical in exposed situations by enabling sea-works to be constructed independently of the state of the weather, for which purpose the Author believes it to be well suited.

Breakwaters might also be expeditiously constructed of huge concrete blocks without staging, by forming the blocks on a travelling incline, by aid of a 3-ton revolving derrick crane[1] at the upper end of the incline, down which incline the blocks would be launched, when finished, in a slanting position, into place on a bed of plastic concrete. Each block might be made 135 feet long, 46 feet wide, and 20 feet high, weighing about 6,000 tons, so as to form a complete section of the breakwater, about 66 feet in length, in a depth of 23 feet at low-water and with a range of tide of 20 feet. The main body of the concrete block might be composed of 10 parts of ballast to 1 part of cement, with an outer coat of masonry or of concrete, of which one-third was cement; and if the block was strengthened by a skeleton steel framing braced longitudinally and transversely, it could be launched without fear of fracture soon after completion. The blocks being on a slope of about 3 to 1, or only a little less than the angle of repose, could be launched with a small amount of force; or the launching-ways could be at an inclination of 2½ to 1, and the blocks lowered down into position by brakes. The sliding down of the block, below high-water level, along the top surface of the previously laid block, would be facilitated by timbers built into the under surface of the upper block sliding on the timbers in the upper surface of the under block. By filling up adjacent recesses, left along the centre of the upper and under surfaces of each block, with plastic concrete and Portland cement grout, the successive blocks could be connected together into a monolithic mass. If the block, instead of being formed complete before launching, was constructed and launched in successive stages, so as to have only a third or fourth of the block above water at one time, the travelling incline might be made smaller. By this system, work could be carried on almost continuously throughout the year, at the rate of 2 feet a day or 600 feet per annum.

The communication is illustrated by a series of tracings, from which Plate 1 has been compiled and engraved.

[1] Minutes of Proceedings Inst. C.E., vol. lxxiii. Plate 12.

(*Paper No. 2164.*)

"Colombo Harbour Works, Ceylon."

By JOHN KYLE, M. Inst. C.E.

THE idea of providing Ceylon with an artificial harbour was originated by the Earl of Carnarvon, who, in 1866, suggested the improvement of the natural harbour at Pointe de Galle with this object. In 1870, however, the Governor, Sir Hercules Robinson, pointed out that Colombo was the best place for providing increased harbour accommodation. It was shown that Colombo, being only 30 miles out of the direct course between Aden and Galle, and 18 miles from the direct course between Bombay and Galle, might serve as the great coaling station of the east; and that Colombo was a more accessible port than Galle, being free from the treacherous currents which exist off Galle. Moreover the tonnage of Colombo had increased more than thirteen-fold between 1830 and 1869; and the trade statistics proved that a revenue of £32,000 might be raised for the harbour works. Accordingly a report was obtained from Mr. R. Townsend, M. Inst. C.E., who advised the construction of a harbour on the site of Colombo Lake, protected by a breakwater seawards, and a rubble jetty on the land side, with an entrance between them in the rear of Custom House Point, at an estimated cost of £720,000.

In 1872 Sir John Coode, Vice-President Inst. C.E., having had Mr. Townsend's scheme submitted to him, advised the construction of a breakwater from Custom House Point, as best suited to meet the requirements of the Colony; and this recommendation having been approved by the Home and Colonial Governments, Sir John Coode was instructed, early in 1873, to take the necessary steps for carrying out the work.

The scheme, as executed, comprises the sheltering of a water-area of 502 acres, at low-water, by a breakwater, 4,212 feet long; the reclamation of some of the foreshore as a site for coal stores; and dredging some of the shallow portion of the harbour to a depth of 26 feet at low-water (Plate 2, Fig. 1). As it was resolved to construct the works without a contractor, the Author was appointed Resident Executive Engineer in May 1873. During a visit of three months to the Colony, he investigated all the conditions of

the site; and having arranged for the opening-out of a suitable granite quarry, the formation of a block-yard at Galle Buck, and the construction of lines of railway from the quarry to the main line, and from the Colombo terminus to the works, he returned to England, when the plans and arrangements for carrying out the works were settled with Sir John Coode; and in June 1874 the engineering staff arrived at Colombo. The foundation stone of the work was laid on the 8th of December 1875, by H.R.H. the Prince of Wales, Hon. M. Inst. C.E., during a visit to the Colony; and the works were completed in April 1885, at a total cost of 84,62,484 rupees, or £705,207.

Preliminary Works.

Quarry.—The quarry is situated at Mahara, 1¼ mile from the main line, and 11 miles from the Colombo terminus. About 8 acres of land were obtained, rising about 98 feet above the service railway, and containing about 500,000 cubic yards of granite having a specific gravity of 2·625. The first train-load of rubble was delivered at Colombo in October 1874; the minimum output was 100 tons a day, and never exceeded 600 tons owing to the limited extent of the working floor-space. The top rock was bored from 12 to 18 feet deep by 2½-inch drills, and blasted down in masses by pebble-grain powder; and then redrilled with 1¼-inch holes, from 6 to 8 inches deep, and broken up by ¾ to 1½-oz. charges of Nobel's dynamite. The firing was done out of working hours; and the blasting-operations were all effected by free labour, whilst convicts were employed for loading the wagons. Accommodation was provided at Mahara for three hundred convicts, who worked in the quarries, and proved an important addition to the breakwater staff and a great profit to the Colony.

Branch lines.—The breakwater branch commences at the Colombo terminal station, and, skirting the lake along Norris Road, terminates at Galle Buck. It has a total length of 1 mile 62 chains, and cost £17,210 exclusive of land. The Mahara quarry line, having a length of 1 mile 34 chains, branches off from the main line at the ninth mile from Colombo, and cost £5,979.

Block-yards.—The site at Galle Buck had to be levelled by the removal of 26,368 tons of granite and 66,726 cubic yards of earth; and 6,860 tons of the granite were utilized in the construction of a north and south dry stone sea-wall, reclaiming some bights along the shore. Workshops were erected, and lines laid down on this site (Plate 2, Fig. 1). A cement-shed, 205 feet by 35 feet, was

erected near the stone-breaking and dry skip-filling yards, with a cement floor raised on débris 2 feet above the ground; being close to the sea, it was walled in on three sides and roofed without ventilation, so as to exclude the sea-air from the cement. Two cement floors, each 1,000 feet by 53 feet, formed of a $2\frac{1}{2}$-inch layer of cement mortar placed on 18 inches of well-packed rubble, were laid down for block-yards, with three lines of way between them and a service road running along the centre of each floor (Plate 2, Fig. 1). Two 32-ton overhead travelling-cranes, tested to 42 tons, and two 3-ton travellers, stretched across the floors, could traverse their length on outside rails to a 53-foot gauge; the former being employed in loading the blocks when made, and the latter in discharging the dry and wet skips into the machines and moulds.

Root Work.

Sea-wall.—The Root work, extending seaward of Custom House Point, and covering an area of 5 acres, formed a starting point for the breakwater, and enclosed a reef of dangerous rocks. On the sea side, it is protected from the south-west monsoon by a wall of three courses of 7-ton concrete blocks, with occasional buttresses of blocks at the back, resting upon a rubble mound at about half-tide level and backed with rubble (Plate 2, Fig. 4). The tipping of rubble was commenced in January 1875; 28,259 tons of rubble were deposited in the work, at a cost of £7,109; and four hundred and ninety-eight blocks were laid, at a total cost of £3,321. The blocks were laid by the aid of two sheer-poles and 3-ton hand-winches; and the quarrying of the stone, and the manufacture and setting of the blocks, were performed by convict labour.

Depot-wharf wall.—This wall, under shelter of the breakwater, consists of concrete cylinders with a concrete-in-mass superstructure and backed with rubble. A portion of the wall, on each side of the eastern corner, is built on a double row of 5-foot cylinders, founded 16 feet below low-water ordinary spring-tides; and the remainder of the north-east wall, nearly up to the breakwater, is on 7-foot cylinders, founded 28 feet below low-water, with concrete-in-mass capping joggled 6 and 9 inches respectively into the cores of the cylinders (Plate 2, Figs. 2 and 3). The junction piece, up to the breakwater, is built of concrete-in-mass on a boulder reef. The total length of the wall is 829 feet; and the coping is 9 feet above low-water. The 5-foot cylinders were in sections, $3\frac{1}{2}$ feet deep and 3 feet internal diameter, and the 7-foot, 4 feet 10 inches deep with a $4\frac{1}{2}$-foot core, weighing 3 and 7 tons respectively. The ordinary

rings were composed of 3 parts of stone, 2 of sand, and 1 part of cement; but the cutting-rings were made with one-fourth part of cement. The total cost was £22,317.

Rubble and earth filling.—The surface level of the Root is 10 feet above low-water. The filling consisted of 131,424 cubic yards of earth and 26,368 tons of rubble, obtained from Galle Buck, from a "cabook" cutting on the Kandy Railway, and from harbour-dredgings, and cost £17,329. The surrounding conditions, and the expedients necessary to preserve the filling from the backwash of each south-west monsoon, rendered the Root work costly.

Abutment block.—A huge block of concrete-in-mass, weighing 320 tons, deposited within timber casing lined with canvas, in 16 to 24 feet of water, on the jagged rock, forms an abutment for joining the breakwater to the Root. After the destruction of one casing by a westerly storm, the work was completed in April 1876, at a cost of £976.

Breakwater.

Delivery of rubble.—The stone was loaded at the quarry into side-tipping wagons, and on the arrival of the train of about twenty-four wagons at Galle Buck, it was distributed between the yard and the shoot at the depot wharf. A train of ten wagons was run alongside the shoot, and the rubble tipped into the well of the hopper-barge. The iron shoot, 13 feet by 11 feet, was supported at the sides by a timber frame pivoting between uprights through which the lowering and raising chains were reeved. The amount of rubble thus delivered into the hopper-barge was 141,147 tons.

Depositing from hopper-barge.—The 80-ton steam hopper-barge, running 6 knots an hour with a full load, was loaded from the shoot alongside the depot wharf; and on reaching her destination ahead of the breakwater, the exact position for dropping the cargo was ascertained by means of high diamond and circular-shaped beacons on shore, and floating beacons in the sea. Five tiers of cargoes were deposited on the transverse line by means of marks on the vessel's gunwale, corresponding in shape to the land beacons numbered from 1 to 5. Three transverse sets of buoys were placed at the end of the work, marking the lines of the tiers of cargoes; and the man stationed at the number of the cargo to be dropped shouted out "let go" on getting into the corresponding beacon line. Cross sections of the mound are given in Plate 2, Figs. 5 to 7.

The top of the mound was usually kept about 2 feet below the foundation-level of the pier-wall, and was subsequently raised by

the hand-cargo boats and divers. The length of mound completed each season varied from 500 to 900 lineal feet, being kept in advance of the pier at least a length equal to the progress of the wall during the same season; so that, having a whole season to consolidate before receiving the superstructure, the chances of undue settlement were reduced to a minimum.

Berms and Hearting.—During the block-setting season, thirty-five wagon-loads of stone were daily discharged from the wall into the hand barges alongside, from whence they were thrown over on to the mound, as directed by the divers. Eighty-five wagon-loads a day were at the same time deposited on the sea and harbour berms of the breakwater, to make them up to their full section; and a portable shoot of old rails was provided for this purpose, overhanging the face of the wall, having the same slope as the bottom of the tip-wagons at their angle of discharge, and capable of withstanding the shock of falling pieces of rock of 3 tons weight (Plate 2, Fig. 7). Large blocks could thus be deposited, over a core of ordinary rubble, for protecting the berms in bad weather; and the berms were always fully made up at the close of each season. At the commencement of the setting-season, a series of cross sections of the mound were taken, 50 feet apart, whereby any settlement was detected, and was then made up with 3½-ton rubble. In shallow water, the berm was exposed to the action of the sea for about three years before reaching the condition shown (Plate 2, Fig. 5).

The quantities of rubble deposited in the mound, berms, and hearting, were 141,147 tons by the hopper-barge, 104,479 tons from boats, 59,822 tons on berms, and 14,917 tons by hand in hearting.

Bag-work on Sea Berm.—An apron, 24 feet broad, composed of 10-ton bags of concrete, protects the top of the sea berm from disturbance (Plate 2, Figs. 5 to 9). The bag, having been sewn up on five sides, was adjusted in a skip, carried on a wagon under a shoot, through which concrete was poured into the open mouth of the bag from the mixer-skip. The top of the bag was sewn up during its journey to the derrick, by which the skip with its contents was hoisted, run out, and lowered, and the bag dropped into its place (Plate 2, Fig. 6). No damage was done to any bag, either by the sea, or by the rubble mound on which it fell. The depositing of the bags was commenced on February 11th, 1884, when the progress sections showed that the first length of 2,150 feet of berm, having attained its normal slope, was ready to receive the bags; proceeding landwards, the whole seven hundred and

twelve bags were deposited, up to the junction line, by the 2nd of April following. About sixteen and three-quarter bags, in a single row, covered a length of 100 feet; and the average space between each bag did not exceed 3 inches.

The total cost of the rubble mound, berms, hearting, and bag-work, up to the end of 1884, was £106,553.

Block-making for Pier-Wall.—By the end of 1876, six hundred blocks, averaging 20 tons each, had been made and stacked in the yards. Owing to the unavoidable deficiency of storage space, the blocks were stacked close together, two deep, in the yards, and also two deep on the harbour-wall of the breakwater, by which means two thousand blocks were in stock on the arrival of the setting season; and all blocks over six weeks old were set in the work.

During the monsoon season, the prisoners worked eight hours a day; in the setting season, a twelve-hour system was adopted. In the slack season, one hundred and sixty-six prisoners manufactured six blocks a day; whilst during the twelve-hour system, three hundred and nine prisoners made twelve blocks a day, without increasing the cost per cubic yard. A charge of 37½ cents per day of eight hours was made for each prisoner employed, which included the guards and police in charge of the gangs.

The trains of dry materials consisted of eight wagons, with two skips in each; and the skips were divided into three compartments, containing stone, sand, and cement, in the proportions of 6, 2, and 1 respectively. Travelling 3-ton gantries, with an overhead travelling steam-winch, were used for lifting the dry, and depositing the wet materials. When the mixture was poured into the mould, two masons and four prisoners forced it into the corners and sides of the mould with iron-shod rammers; after three days the mould was removed, and three weeks later the block was stacked.

Block-setting in Pier-Wall.—Twelve divers, with nineteen attendants, prepared the bed on the mound in advance of the wall; they worked three and a half hour shifts, in relays of four divers each, at a total daily cost of £9 7*s.* 6*d.* The divers used four 6-foot lengths of 50-lb. rails for levelling the bed, which were ringed at each end for moving them about; and they finished off the surface with a trimming of small quarry chips.

The concrete blocks were set by a Titan (Plate 2, Figs. 10 and 11), the first block being set on the 12th of December 1876. The Titan could carry a load of 40 tons, on an overhang of 28 feet; its weight, including rubble-ballast, water, fuel, &c., was 180 tons; and it cost £5,562 set up in Colombo. The foundation blocks,

standing on the slant on the truck, with the lewises vertical, were lifted by the Titan in that position; but the other blocks, being square, were lifted in the yard on to the truck by a pair of outside grips, and when canted on the truck to the setting angle of 68°, the lewises were dropped in vertically, and the block was raised and set by the Titan. The five courses, of three blocks each, in the 34-foot wall were set in seven hours (Plate 2, Fig. 7); and under the most favourable conditions, thirty blocks were set in twelve hours. The Titan, in passing over the work as it progressed, made it settle from 3 to 5 inches; and a further settlement of 5 or 6 inches was effected by the waves of the south-west monsoon, giving a total maximum of about 9 inches, for which allowance was made by keeping up the scar end as the work advanced.

Along the inner portion of the breakwater, consisting of two walls (Plate 2, Fig. 5), a 40-ton steam derrick was used for setting the harbour-wall blocks; it travelled on the sea-wall, and its jib hung over the harbour-wall.

The lines for the Titan, derrick, and trains, were fixed upon longitudinal balks, secured to the wall by dowels and concrete-in-mass, so as to resist the attacks of the south-west monsoon waves, and enable the Titan to be drawn to land after the close of the setting-season; for the experience of the first stormy season showed that it was not safe to leave the Titan out on the breakwater.

Joggle Grooves, Scar End, and Capping.—The joggle grooves left between each row of sloping blocks (Plate 2, Fig. 10) were filled up to high-water level with strong concrete in bags, dropped into the hole and rammed down hard.

Towards the termination of each season, before the setting in of the south-west monsoon, the three last upper courses of the scar end were secured together, through their lewis holes, by four 2 inch wrought-iron screw-bars, stretched longitudinally over the work, to prevent the sea disturbing the blocks.

The final capping of the pier-wall with concrete-in-mass binds all the top blocks together, and gives additional weight to the structure. It is 48¼ feet broad across the wide inner portion of the pier, and 31⅝ feet across the outer portion; and 4 feet deep in the centre, and 3½ feet at the sides. The concrete was mixed by the machine in the yard, and sent off in a series of three trains of one wagon, each carrying four skips.

Pier-Wall.—Near the land, the wall was founded 13 feet below low-water; this was increased to 16 feet at 977 feet, to 20 feet at 2,070 feet, and continued at this depth close up to the pier-head,

where the foundation was stepped down to 23¾ feet below low-water (Plate 2, Figs. 5, 6, 7, and 9). The block-work rose to 8 feet above low-water; and the capping raises the centre of the wall to 12 feet above low-water.

The first 1,326 feet of the pier was built with a sea- and a harbour-wall, having an interval between them of 14 feet, filled in with rubble (Plate 2, Fig. 5). The sea-wall consists of two foundation blocks, 13 feet long and weighing 28 tons each, supporting three courses, 24 feet long, composed of blocks of 14 to 26½ tons each. The harbour-wall is 12 feet wide, making a total width of 50 feet. At 1,326 feet from the commencement, a single wall, 34 feet in width, was adopted, with four to five courses of blocks weighing from 16½ to 31 tons each (Plate 2, Figs. 6, 7, and 10). The sloping joints are 5½ feet apart on the square, and have an inclination of 68° to the horizon (Plate 2, Fig. 11). The last sloping courses of blocks, and the closing blocks up to the pier-head, were laid before the close of the setting-season, in March 1883 (Plate 2, Fig. 9).

The total number of blocks placed in the pier were nine thousand six hundred and fifty-six, containing 124,984 cubic yards; and their total cost in position was £247,313.

Pier-Head.—The pier-head consists of a circular block of concrete-in-mass, 62 feet in diameter and 27 feet high, surmounted by another block 60 feet in diameter and 11 feet high (Plate 2, Fig. 9). The lower portion, being under water, was deposited in a wrought-iron circular tank, formed of ¼-inch plates stiffened and braced by T-irons and angle-irons, with a square corner to fit on to the pier-end. The tank was ballasted with 400 tons of concrete-in-mass, and subsequently towed into position with a further load of 600 tons, which left it a freeboard of 5 feet. A favourable opportunity occurring on the 1st of December 1883, the groove of the caisson was drawn up to the tongue of the pier-end; the water was then let in, and in six minutes the caisson settled down upon its bed; and by the 8th of January 1884, the filling of the tank with concrete was completed. A heavy sea tore away 50 feet by 14 feet of the sea side of the plating, leaving a gap which was filled up in five days by one hundred and seven 10-ton concrete bags. The completion of the pier-head was deferred, after being raised to the service-road level, till the landing stage had been constructed. The outside circular blocks were then raised to the floor-level, and the interior was filled with concrete-in-mass; in the following season, 1884–5, the pier-head was surmounted by a 7½-foot parapet.

Landing-Pier. — A landing-pier projects from the pier-head, 120 feet long, 21 feet broad, 37¾ feet deep, and founded 24 feet below low-water (Plate 2, Fig. 8). Being sheltered by the breakwater, it is provided with landing-stairs, for the light-keeper to have access in all seasons. The blocks, nine hundred and twenty in number, were set in forty-nine days by a 7-ton overhead travelling-crane from a timber stage erected as shown on the section; and 186 cubic yards of concrete-in-mass were laid on the top. The total cost was £7,039.

Lighthouse Tower.—A circular tower, 36½ feet high, was erected on the pier-head, built of a moulded concrete-in-mass basement and concrete blocks above; it carries a second-order light, with its focal plane 58 feet above low-water (Plate 2, Fig. 9). The external diameter of the tower below the coping is 17 feet, and the internal diameter is 11 feet. The lighthouse contains an oil-room at the base, over which are a store-room, a bedroom, a living-room, and a watch-room, with concrete floors supported on rolled iron joists, and a cast-iron staircase.

Progress of the Work.—The amount of work accomplished each season, up to 1882-3, is shown in the following Table :—

Season.	Working Days.	Blocks set.		Length of Wall.
		Sea Wall.	Harbour Wall.	
	Number.	Number.	Number.	Feet.
1876–77	123	617	—	375
1877–78	134½	923	141	556
1878–79	23	107	—	74
	198½	—	491	680[1]
1879–80	88¾	822	—	458
	139⅓	—	355	434[1]
1880–81	130½	1,953	—	946
1881–82	129⅔	2,340	—	952½
1882–83	118	1,907	—	787⅔
Totals . . .	1,085¼	8,669	987	4,149⅙

In April 1878, an unusually heavy south-west monsoon set in, and swept away a 14-ton block from the second upper course of the scar end; increasing in strength in July, the sea drove in the scar end of the sea-wall, which was 700 feet in advance of the harbour-wall, to the extent of 15 inches, pivoting on a point 150 feet landwards, and lowered the end 12 inches, diminishing to nothing 450 feet in. Accordingly, to avoid damage, the exten-

[1] These lengths of harbour-wall do not form part of the total length.

sion of the sea-wall was stopped till the harbour-wall was brought up to it. During the season 1879–80, the harbour-wall progressed very slowly, owing to large quantities of sand having been washed on to the foundations by the south-west monsoon of 1879, which had to be removed by divers. For instance, in November and December 1879, only four sloping sections of the harbour-wall were set; whereas twenty-four sections of the sea-wall, having double the width, were set in the same time.

In the eighth season, 1883–84, with one hundred and ninety-five working-days, the pier-head up to quay-level, the lighthouse tower, the landing-pier, and the apron of concrete bags on the berm, were completed, comprising 6,922 cubic yards of concrete-in-mass, and three hundred and fifty-three 3-ton, and nine hundred and twenty-eight 7-ton blocks altogether.

The work was finished in the season 1884–85, comprising the completion of the pier-head and the lighthouse fittings, and also the concrete-in-mass capping from the pier-head to the shore, containing 15,000 cubic yards.

Settlement.—The amount of subsidence which took place during each south-west monsoon was carefully measured. The maximum settlement along the centre line was 2 inches, and the average 1½ inch. In 1877, there was a settlement of 18 inches on the sea side; and during the monsoon of 1884, a maximum settlement of 4 inches occurred between 400 and 500 feet from the shore.

Dredging, Reclamation, Moorings, &c.

Dredging.—The position of the 85½ acres in the harbour, to be dredged to a depth of 26 feet at low-water, is shown by a dotted line on Plate 2, Fig. 1; the amount to be dredged was 887,459 cubic yards, of which 678,459 cubic yards had been completed up to 1884. The sheltered water-area in the harbour is 502 acres at low-water, 329 acres with a depth of 18 feet and upwards, 242½ acres of 26 feet and over, and 90½ acres of 30 feet and more. A single ordinary bucket-dredger, of 75 nominal HP., was employed, capable of dredging in 29 feet of water. The dredgings from the harbour were conveyed 4 miles out to sea, and dropped in 15 fathoms of water by a hopper-barge carrying 500 tons, and making three trips a day in full work, or on the average two and a half trips. The barge cost £11,333 delivered at Colombo. An auxiliary barge took its place whilst absent on its trips, and carried away three cargoes of 75 cubic yards each.

Reclamation.—A rubble mound, 9 feet wide at the top, and

averaging 37 feet in width at the base, and 14 feet in height, extends 2,600 feet along the southern shore-line of the harbour, reclaiming an area of 20 acres, which was filled up with harbour-dredgings (Plate 2, Fig. 1). A backing of cabook, 6 feet in width, was deposited behind the mound; and the quay-level was completed with a 12-inch layer of cabook, 5 feet above low-water. The dredged sand was brought to the landing-stage in two trains of five barges, containing 20 tons each, towed by a steam-tug. The total quantities of material used were 51,475 tons of rubble and 290,641 cubic yards of cabook and dredgings, at a cost of £45,344.

Moorings.—Four tiers of six buoys each were fixed parallel to the breakwater (Plate 2, Fig. 1). The first tier is 300 feet from the pier-wall; and the buoys are 600 feet apart each way.[1] Twenty-five steamers of the largest class can moor in depths of from 26 to 40 feet of water; whilst there is space at low-water for a great number of vessels drawing from 6 to 26 feet. A vessel entering the harbour at night steers into the line of the fairway lights, where a passage of 600 feet is kept open for convenience in berthing. The cost of the moorings was £7,411.

Revenue of the Harbour.—The collection of revenue from the new harbour began with 1883; during the two years 1883 and 1884 it amounted to 4,11,318 rupees and 4,08,566 rupees, equivalent to about £34,276 and £34,047 respectively.

Management of Works.—The whole of the drawings from which the works have been executed, including the contract drawings for the special plant and machinery, were prepared by the Engineer-in-Chief, Sir John Coode; and the works were carried out by the Author, who had the charge and management of their execution, as Resident Engineer, from the commencement, Mr. Charles Good, Assoc. M. Inst. C.E., being the Assistant Engineer. The special plant and machinery were constructed, and their working was thoroughly tested before leaving England, under the superintendence of Mr. William Matthews, M. Inst. C.E.

The Paper is illustrated by numerous drawings and diagrams, some of which are reproduced, to a smaller scale, in Plate 2.

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[1] The Author adopted the following method for sinking the collar of the screws. A cylinder, 5 feet in diameter and 6 feet high, was lowered from a barge fitted with suitable gearing, and it was sunk by divers removing the sand from inside. The screw and collar were then lowered into the cylinder, and screwed into the bottom to the full depth; after which the cylinder was removed.

APPENDIXES.

APPENDIX I.

COST OF WORKS.

SUMMARY of GROSS TOTAL EXPENDITURE in CURRENCY and STERLING up to 31st DECEMBER, 1884, with ESTIMATE to COMPLETE the WHOLE WORK.

Description of Works.	Expenditure to 31st Dec. 1884.	Estimated Expenditure to complete the Works.	Gross Total Cost of Works.	Expenditure to 31st Dec. 1884.	Estimated Expenditure.	Gross Total Cost of Works.
	Rs. a.	Rs.	Rs. a.	£. s. d.	£. s. d.	£. s. d.
Root work	733,718 76	..	732,718 76	61,059 17 11	..	61,059 17 11
Breakwater mound . .	1,278,644 92	82,350	1,360,994 92	106,553 14 10	6,862 10 0	113,416 4 10
Breakwater pier . . .	3,675,716 13	135,283	3,810,999 13	306,309 13 7	11,273 11 8	317,583 5 3
Harbour-dredging . . .	570,995 41	67,300	638,295 41	47,582 19 1	5,608 6 8	53,191 5 9
Foreshore-reclamation . .	482,580 32	4,280	486,860 32	40,215 0 6	356 13 4	40,571 13 10
Harbour moorings . . .	88,943 77	3,900	92,843 77	7,411 19 7	325 0 0	7,736 19 7
„ leading lights .	933 18	..	933 18	77 15 4	..	77 15 4
Administration	549,860 03	38,100	587,960 03	45,821 13 5	3,175 0 0	48,996 13 5
General workshops . .	545,054 84	30,000	575,054 84	45,421 4 9	2,500 0 0	47,921 4 9
Extraordinary expenditure for work done not connected with construction account, loan charges, &c., &c.	132,681 02	..	132,681 02	11,056 15 0	..	11,056 15 0
Spare gear, tools, and stores not used up	43,142 62	..	43,142 62	3,595 4 4	..	3,595 4 4
Totals . . .	8,101,271 00	361,213	8,462,484 00	675,105 18 4	30,101 1 8	705,207 0 0

APPENDIX II.

Tests of Cement and Concrete.

Table showing the relative Transverse Strength of Concrete Blocks, 4 feet long by 1 foot wide by 1 foot deep, broken by Hydraulic Pressure brought to bear on a 6-inch Timber placed across the centre of the Block, the end Supports being 3 feet apart inside.

Fresh water was used in mixing, and the concrete blocks were kept wet for the three months that intervened between making and testing.

No.	Materials.					Blocks Broken.	Breaking Strain.			Average Breaking Strain.	Average Breaking Strain per Sq. Inch of Section.
	Cement.	Sand.	Hand Broken Stone 3½ ins.	Machine Crushed Stone 1½ in.	River Gravel.						
	Proportions.					No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	1	2 coarse	..	..	..	3	20,160	14,560	[1]4,480	17,360	120
2	1	2 fine	..	..	..	3	10,080	14,000	14,000	12,693	88
3	1	2	4	2	..	3	5,880	7,560	4,200	5,880	41
4	1	2	..	..	6	3	4,480	6,720	4,480	5,227	36
5	1	2	..	6	..	3	6,160	3,920	3,640	4,573	32

[1] This test was a failure, as the indicator was found to be pressing on the dial, and is not taken into account in the result.

Table showing the Crushing Weight required to break Cement and Concrete blocks, 3 inches cube, by Hydraulic Pressure.

Fresh water was used in mixing, and the concrete blocks were kept wet for the three months that intervened between making and testing.

No.	Materials.					Blocks Broken.	Crushing Weight.			Average Crushing Weight.	Average Crushing Weight per Sq. inch Area.
	Cement.	Sand.	Hand Broken Stone 3½ ins.	Machine Crushed Stone 1½ in.	River Gravel.						
	Proportions.					No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	Neat	..	..	..	..	3	42,560	56,000	45,920	48,160	5,351
2	1	2 coarse	..	..	..	3	26,880	24,640	21,840	24,453	2,717
3	1	2 fine	..	..	..	3	15,680	15,120	15,680	15,493	1,721
4	1	2	4	2	..	3	36,400	37,520	40,320	38,080	4,231
5	1	2	..	..	6	3	22,400	17,360	20,160	19,973	2,219
6	1	2	..	6	..	3	21,840	22,400	15,680	19,973	2,219

The cement in barrel, stored in the cement-shed, maintained its quality for at least a year. Three tests were made in every case, with a sample of each delivery of cement, by a Michel machine.

The tests prove that induration increased steadily till the cement attained its average maximum strength in about twelve months. The minimum tensile strength allowed in the concrete was 200, 400, and 500 lbs. after two, four, and seven days respectively. When a test indicated a tensile strength less than the above, an additional quantity of cement was added to the mixture, in which the cargo of cement was being used, in proportion to the deficiency in strength, according to a fixed tariff hung up in the cement shed.

APPENDIX III.

Tests of ordinary Ceylon Bricks.

Table showing the Crushing Weight required to break ordinary Ceylon building-Bricks. Hydraulic Pressure brought to bear on a Half brick, 4½ inches by 4½ inches, and 2 inches thick.

No.	Weight of Full-sized Brick.	Crushing Weight required to Break Half Brick.	Average Crushing Weight per Square inch Area.	Remarks.
	Lbs.	Lbs.	Lbs.	
1	5¼	68,320	3,374	
2	6½	40,320	1,991	Very soft brick.
3	5¼	78,400	3,872	

APPENDIX IV.

Tides.

The range of tide during the north-east monsoon is from 5 to 37 inches, and from 5 to 30 inches during the south-west monsoon, and averages about 24 and 18 inches respectively. The extreme highest and lowest tides occur at full moon in April, when the tide falls to the zero of the gauge and rises 40 inches within twenty-four hours.

Sir John Coode. that he was making a large demand upon the faith of the Ceylon Government (represented in this country by the Crown agents' department of the Colonial Office) to sanction such an outlay. The authorities gave him, however, their entire confidence, and he thought he was justified in saying that they were eminently satisfied with the result. If, looking back upon the past, he had found that the system was not what it should have been, he would be willing to admit it; but so far from that being the case, if he were beginning the work again under similar conditions, he should follow practically the same plan. Although the structure was composed of separate blocks he held that it was monolithic in its character. The result was obtained first by giving a large amount of bond to the work. The blocks generally broke-joint to the extent of 5 or 8 feet. Then there were five large joggle-grooves running from the top to the bottom. Those grooves were 18 inches in the transverse direction, and while they admitted of the breakwater subsiding in the case of a treacherous piece of ground, they preserved it from being broken. Before the breakwater could be disturbed transversely, it would be necessary to fracture what was equivalent to a wall of 7 feet 6 inches of concrete from the top to the bottom; so that he thought that the monolithic character of the structure had been well preserved. He had been asked by a member of the Institution who could not be present what was the effect of a tropical climate on concrete, thinking that the works of Colombo would be a good example? After the temperatures which he had mentioned, and remembering that Colombo was 7° north of the Equator, he thought that the test was about as severe a one as could be applied. He would direct attention to a photograph representing a piece of work that had been executed for ten years, and that, he thought, would be a very good answer to the inquiry that had been made. It was satisfactory to know that a series of sections had been taken across the harbour at close intervals every year during the last eight or ten years, and he was justified in saying that there had been no silting. The soundings were exceedingly good: they were taken by a wire line to ensure accuracy in the horizontal measurements, and by accurately adjusted chains for the depth. With regard to the size of the harbour, the area enclosed within the breakwater was fully 500 acres. It was well known that there was ample depth of water in the general body of what was then the roadstead; but it was necessary to know what was the character of the ground in shore; and a few years ago some borings were made near the low-water margin, the result of which had been to show that it was possible

to dredge to a depth of 5 fathoms over the whole of the area, so Sir John Coode. that, allowing for the slopes, 450 acres of that depth might be available should occasion require; it was simply a question of dredging. He knew something of the artificial works that had been constructed elsewhere, but he did not know of any work which had been tested to the extent of that at Colombo. What took place at, and just after, the burst of every monsoon about the month of May, might be seen from the photograph produced, an instantaneous one. The height of the top of the water was commonly 120 feet above sea-level, and occasionally much more. No one would dispute the elementary law of forces and motion, that action and reaction were equal and opposite; he assumed, therefore, that the elevation attained by the sea was a measure of the stroke which the structure had to sustain. The length was about 3,000 feet, and the stroke by the sea at one and the same moment often caused the water to rise to the height of 120 and sometimes 150 feet. That, he thought, was a test such as very few works had to undergo; it was not simply a question of hours or of days, but a question of weeks. It went on with very little variation from four to six weeks. He had stood under the traveller represented in the photograph and looked along the work when the sea was striking it. It was rather an anxious sight for an engineer who had constructed a work of that kind, for the stroke was tremendous. He had naturally asked himself why was it that the wave struck the work so violently, and caused the sea to rise to such an enormous height? He believed the reason was that, during the occurrence of the heavy monsoon swell, it was not a broken sea, it was the swell itself which came in with a great roll. He should like the members to realize the difference between the shock from a wave which was highly aerated, such as a broken wave occurring in storms on our own coast, and a stroke like that of the sea during the monsoon swell. That tremendous stroke, he believed, was due to the body of comparatively unaerated, or partially aerated, water. He would endeavour to illustrate the difference, between water which was aerated in the ordinary sense, and water which was only partially aerated, by a water-hammer. The tube was not a perfect vacuum, but the air was rarefied to the extent to which it was possible to rarefy it by boiling. The water was not sea-water, but distilled water coloured with indigo in order that the effect might be shown. By shaking the tube like a bottle of medicine, the noise of the water against the glass, resembling a blow from a hard substance, could be distinctly heard. He therefore concluded that the stroke upon any given

Mr. Parkes. at the bottom of the sea, amounted to about 7*d.* per cubic yard of the work set by it. The amount shown by the figures given in Mr. Kyle's Paper, in connection with Sir John Coode's Titan, was 11*d.* per cubic yard. Those certainly were not very high figures. He thought that any other system of using concrete in the sea would necessitate a larger amount of cement, which would more than balance the cost of the machinery on a work of any considerable magnitude. Of course, in the case of small works, the use of machinery would be comparatively more expensive. Mr. Kinipple had made a suggestion with regard to grouting shingle, and stated that he had done it successfully. Mr. Parkes had always had some suspicion of the amount of success to be attained by grouting shingle; and he might be permitted to explain an experiment that he had made twenty-five years ago, with a view of adopting that very plan. After some preliminary experiments which he thought promising, Messrs. J. B. White and Brothers had kindly allowed him, on their premises, to place in a wooden box 3 feet by 2 feet by 18 inches, a quantity of clean shingle. That was placed in a tank. He measured the quantity of water required to fill the interstices between the shingle, and a corresponding quantity of cement was put aside. The tank was then filled with water, up to within an inch or two of the top of the shingle. He then had the cement formed into grout in the ordinary manner, and it was poured in among the shingle. It disappeared, and everything seemed to go on in a promising way, but he seemed to have succeeded sooner than he expected. He found that the case of shingle was filled up to the top with grout, so that he could put no more in, before one-half of the cement had been expended. His first impression was that it had become choked among the shingle, and that the case was not getting properly filled. The water was thereupon run out of the tank, and the sides of the box were removed, when everything was apparently complete; there was a perfectly smooth surface. He then broke up the mass, and he found that every cranny was filled with cement. That was kept for days and weeks, in the hope that it would harden, but to the end he could scratch it with his nail—it never hardened at all. He feared in many cases in which cement had been grouted in that way, the interstices were simply filled with a soft material, which was really decomposed cement. In order to test the correctness of the conclusion, he had made some further experiments. He obtained some cylindrical glasses and got samples of cement from various makers. He put a certain quantity of cement into the bottom of a glass, and

then poured in about as much water as would be used for grouting, stirred it up, and let it settle. He found in every case that the quantity of solid sediment was from two to three times the depth of the cement put in. The cement, by the excess of water, appeared to be disintegrated completely. The upper part never hardened, but at the bottom there was a thin hard layer which appeared to be nothing but the clay that had been mixed and burned with the chalk. He accordingly drew the conclusion, and he still held to the same opinion, that an excess of water was detrimental to the cement. It was less so, he believed, in practical work than in experiments, but that it was so he felt no doubt whatever. Some confirmation of that was given by the fact, which was familiar to engineers and others accustomed to testing cement, that they could gauge a briquette and make it break at almost any stress, from its maximum strength downward, by simply using more or less water in preparing it. To get the full strength of the cement, the minimum amount of water must be used. There was one point that Mr. Kyle might add to his Paper with advantage, namely, the proportions of cement used in making the concrete. In the record of experiments in Appendix II, the proportions were given, and the one which appeared to be most successful was No. 3, but it was not stated whether the same proportions had been adopted for the blocks. It appeared that no masses of stone had been put into the blocks. It was a common practice which he had followed himself, without having any suspicion that there was anything wrong in it, in making blocks, to incorporate lumps of stone, taking particular care that they were well embedded in concrete, and did not come near the surface. If Mr. Messent was right in saying that granite rubble was as good as concrete, he did not think that those masses of stone could do any harm; but the fact that Sir John Coode had not adopted this practice, would seem to suggest that he was of a different opinion. That it might be overdone was obvious, and it required great care; but the system was economical, and it ought not to be neglected unless mischief was done to the concrete thereby. Forty years ago he was engaged in studying Newhaven Harbour, under the late Mr. Walker, Past-President Inst. C.E. Mr. Carey had given an interesting *résumé* of the history of the harbour, but he appeared accidentally to have omitted the part that Mr. Walker had taken in the matter in 1846; he referred to a report based upon a survey which Mr. Parkes had made under his instructions. The most important feature of Mr. Walker's suggestions, as compared with those of previous engi- Mr. Parkes.

Mr. Hayter. and lias and other hydraulic limes. Indeed, without Portland cement the works described in the Papers could not have been constructed at all with concrete, and probably some of them would not have existed, as the cost would have precluded their construction. But in the last year or two he had met with failures in Portland cement used in concrete in public works. The cement in every case had stood the ordinary mechanical tests, the sand and shingle had been good, and the concrete had set as hard as usual. But after a time expansion had set in. In one case a vertical wall about 35 feet high had lifted about 2½ inches, and in another case a mass of concrete 16 feet thick had lifted from ½ inch to 1¼ inch. In a wall, the first appearance of expansion was indicated by cracking, followed by pieces flaking off the face, and the evil extended until the concrete might at last be destroyed. In every case a white substance of the consistency of cream was seen in the concrete. These occurrences, so different to what he had hitherto experienced, puzzled him much at the time. His attention, however, not long ago had been directed to an article on this subject by Mr. G. Lechartier, published in the "Comptes Rendus des Séances de l'Académie des Sciences," Paris, of the 31st of May, 1886.[1] Mr. Lechartier alluded to many failures in works of all kinds in which Portland cement had been used in some form, all constructed by competent engineers or architects, and in which every care seemed to have been taken. Indeed, so many failures had been referred to, that Mr. Hayter began to think that they were more common in France than in England. But he had since found that they were more frequent here than he had supposed. In all cases Mr. Lechartier had detected magnesia in structures that had failed, and sometimes in large quantities. Mr. Hayter had an analysis made of this cream-like substance, and it was found to contain 80 per cent. of magnesian hydrate, consisting of about two-thirds magnesian oxide (magnesia) and about one-third water. He also had concrete analyzed that had failed, and in every case magnesia was present. Indeed, in one specimen of concrete there was so much of this substance, that the chemist thought the cement had been made from dolomite, not from chalk as an ingredient, but this was not the case. He believed the composition of good Portland cement should be:—

	Per cent.
Lime	50
Silica	30 to 35
Alumina and oxides of Iron	13 „ 15

[1] Vol. cii. p. 1,223. "De l'influence de la magnésie dans les ciments dits de Portland."

In all cements there were other ingredients in small quantities, including magnesia, the quantity of which on no account should exceed 1 per cent. Magnesia in Portland cement did not prevent the ingredients setting, and the concrete becoming apparently as hard as though it were absent; for a time it remained inert when in the mixture, and for months it might be there was no apparent alteration. The magnesia, however, had an affinity for water; every 2 lbs. of magnesia in becoming hydrated took up and solidified 1 lb., or 27·7 cubic inches, of water, and in bulk every ton of magnesia would have to find room for about 18 cubic feet of water. It was in finding room for this water that the concrete became disintegrated. The action went on whether the concrete was in air or in water, but, as might be expected, more rapidly in water; in the former case it became hydrated by the slow absorption of moisture from the atmosphere. Another substance in Portland cement which was injurious, but in a less degree than magnesia, was carbonate of lime. In adding water to the cement, a crystallized double silicate of lime and alumina was formed. But if there was too much lime in the cement it was not taken up by the silica. It did not prevent the setting, but after a while the free lime absorbed carbonic acid from the atmosphere, and was converted into a carbonate of lime, which remained inert in the cement and weakened it. Some cement which had been analyzed for him contained as much as 12 per cent. of carbonate of lime. His object in making these remarks was to point out the necessity of a chemical, as well as of a mechanical, test for Portland cement used in concrete or mortar. This did not seem to have been introduced generally in this country. In his opinion the mechanical tests usually adopted were too high. The ordinary briquette made for testing cement had a sectional area of 2¼ square inches, and it was insisted generally that after seven days this briquette should stand a tensile strain of at least 750 lbs. In order to get this high test within a short period, too much chalk was used in the manufacture. If this were reduced to 500 or 600 lbs., he believed that after the lapse of a short time the cement subjected to the lower test would be harder than that subjected to the higher test. Of course it was all important that Portland cement should be ground extremely fine, and he believed that 95 per cent. should pass through what was called a 50-inch sieve, one having 2,500 holes per square inch. The remaining 5 per cent. should pass through a sieve of 1,000 or 1,500 holes per square inch, and any that would not should be thrown on one side. It was discouraging to an Mr. Hayter.

Mr. Hayter. engineer, when he had done his best to ensure good material and workmanship, to find that after the lapse of a limited period concrete-work executed by him began to show indications of failure. Such an occurrence was apt to throw discredit on an engineer, even though failure might arise from causes which he could not foresee. It would be to the interest of engineers and manufacturers to do what they could to protect themselves in this respect. The conclusion to which he had arrived as regarded the use of Portland cement in concrete or mortar was:—first, that the general introduction of a chemical test as well as a mechanical test for Portland cement was most desirable; secondly, that the ingredients entering into the composition of Portland cement should be generally in the proportions he had referred to above, which would ensure a good cement if properly treated in manufacture, and also that it should contain no carbonate of lime; thirdly, that no Portland cement containing more than 1 per cent. of magnesia should be used. He believed manufacturers would gladly accept these rules, for he had invariably found them desirous to raise as much as possible the standard of the article they supplied. In Germany, a chemical test as well as a mechanical test was the rule and not the exception, and there cement was ground even finer than he had described. This might account for the excellence of the cement manufactured in that country.

Mr. Redman. Mr. J. B. Redman said that the Papers had directed the attention of members to the enormous increase in the manufacture of Portland cement. He well remembered, forty years ago, that in the Gravesend Reach of the River Thames there was scarcely a furnace-shaft to be seen, but now the entire neighbourhood presented the appearance of a manufacturing district; at Greenhithe, Northfleet, Grays, Cliffe, and elsewhere lofty shafts were seen in every direction connected with works engaged in the manufacture of cement, exported for marine purposes to all parts of the world. He was gratified to find that the first Paper upon the list emanated from an old friend, pupil and assistant of his own, who had, with his well-known ingenuity, given a large number of examples of the application of the material under very varied conditions. Some years ago, in surveying for the War Department the coast north and south of Sandown Castle, near Deal, Mr. Kinipple and he came to one of the works of Henry VIII. founded upon the sand dunes, and they found that the entire surface beneath the foundations of the works had been metamorphosed; the sand had become, by the absorption of the lime from the superincumbent masses of masonry, an indurated mass 9 or

12 inches thick resembling sandstone. Mr. Kinipple, who had no doubt had that fact impressed upon his mind, had artificially created the same effect by the aid of a head of water, pouring in liquid cement, and stopping a troublesome sand-spring. Mr. Vernon-Harcourt had stated that the notion had been anticipated by a rival foreign practitioner, a similar injection having been practised at a French port. Mr. Kinipple had given a large number of practical examples within his experience, not altogether of sea-work, some of them being quite uninfluenced by the sea. Several of the sections were of works only proposed. In the adoption of that course an unwritten law of the Institution had been to some extent broken, it being generally understood that Papers of that description should be confined to works that had been executed; but the Author might plead as his apology that he was not the first to transgress, for Mr. M. Scott, M. Inst. C.E., a few years ago, described Blyth Breakwater, and applied the same composite construction to large breakwaters for sea purposes.[1] With reference to the application of plastic cement, it appeared to him that the Authors of several of the Papers had to a certain extent ignored the works of some of their predecessors, as, for example, the application of bag-work by Mr. Cay of Aberdeen, and other practitioners. The concrete in bag-work was so far plastic cement, that it did not attain its ultimate form until it had been resolved into that form by the superincumbent weight. Again, as to the application of large masses of concrete, surely the same might be said of the works at Aberdeen. Nor had any notice been taken in the discussion, or in any of the Papers, of the labours of Mr. Bernays, M. Inst. C.E., at Chatham, who had applied concrete in almost every conceivable form and position, and had made several communications on the subject to the Institution. His works, moreover, were well known by a series of lectures given by him before the military students at Chatham. Mr. Kinipple had referred to experiments made upon cements in 1856. That was a long time ago, and it was at a time when engineers were mainly dependent upon lias-limes, Roman cement, and upon the Italian volcanic product Pozzuolana, for tidal harbour, dock and lighthouse, works. A Paper in a recent number of *Engineering*[2] had described harbour engineering at the present day as almost a disgrace to the profession. That was a statement to which he entirely demurred, and he thought the writer had Mr. Redman.

[1] Minutes of Proceedings Inst. C.E. vol. xviii. p. 72; vol. xix. p. 644.
[2] Vol. xlii. p. 530.

Mr. Redman. ignored the great works, dotting our island coasts, resulting from the labours of Smeaton, Telford, the Rennies, Walker and Rendel, down to the days of Sir John Coode. He only hoped that there were ambitious spirits amongst the members desirous to follow in the footsteps of their predecessors, and that they might never be without their harbour lights.

Mr. Faija. Mr. H. FAIJA said that a wide question had been raised in considering the proportions in which concrete should be mixed. The proportions of 6 to 1 or 8 to 1, whether of sand or large blocks, made a great difference in the result. Mr. Bernays had prepared concrete in the proportion of 1 part of cement to 13 parts of rubble; but then he put large stones into the work, so that it really became a species of rubble masonry with a fairly rich cement-mortar. Mr. Faija was under the impression that the subject of the Papers was to be treated on the assumption that the cement was good, and that therefore no question of testing or analysis would arise; but he thought some notice should be taken of statements that had been made. The presence of magnesia in cement was nothing new; all persons who were acquainted with the manufacture of cement were aware that more than 3 per cent. of magnesia must result in failure. But the failure of cement was not always due to magnesia; it might arise from many other causes; however, he did not think it was of importance for the user to know the cause of failure; it was sufficient if he knew whether the cement was sound or unsound, without going into the causes, which was purely a manufacturer's question. The analysis would not always tell, because it said nothing about the calcination of the cement. He did not think that many persons would like to use cement having only 50 per cent. of lime. With reference to plastic concrete, he believed that the general impression amongst cement-makers and amongst most cement-users was that cement was absolutely ruined if disturbed after it had once commenced to set, but that impression was a wrong one. Cement would set very well after it had been knocked up a second time; it might be taken some years old and be ground up, and it would set even then. There was therefore a great deal more in the suggestion about the use of plastic concrete than most persons would imagine. Mr. Kinipple himself did not appear to know the entire value of what he called plastic concrete; it had other advantages besides that of not being washed away by the sea, and he did not think that it lost strength to the extent suggested. He objected to the term "plastic," as it did not accurately define the state in which the cement or concrete was after being beaten up a second

time; he would prefer calling it a "reset" cement or concrete, as expressing better what was meant. Mr. Faija.

Mr. F. D. Banister considered the Institution was much indebted to the Council for the manner in which the Papers had been grouped together, thus giving the members an opportunity of comparing, not however in any invidious sense, the various modes in which cement could be utilized for harbour purposes. He thought Mr. Messent was rather hard upon Mr. Carey, in making him responsible for figures which were found in an article by an anonymous contributor to the *Daily Telegraph*. There were no such figures in the Author's Paper then under discussion. With reference to the remark of Mr. Vernon-Harcourt, to the effect that no credit was given to Mr. Dyce Cay for the bag-work successfully used at Newhaven, it was stated in Mr. Carey's Paper that Mr. Banister took the idea of bag-work at Newhaven from what he had seen done by Mr. Cay at Aberdeen. He desired to render Mr. Cay every credit for having given him the idea of what he had been able to carry out at Newhaven. Mr. Parkes had referred to some scheme for improvements at Newhaven by the late Mr. Walker, to which allusion had not been made. An allusion, however, had been made to Mr. Walker in Mr. Carey's Paper; but instead of the West Pier being carried out 1,000 feet, as Mr. Walker had suggested, a groyne was carried out 500 feet. With reference to the East Pier, which Mr. Walker suggested should be stopped where it was shown upon the plan (Plate 3, Fig. 1), it was found that that was not sufficient; the current was so great, setting round the end of the breakwater from the south-east, that it brought the sand from Seaford Bay into the harbour. Since that plan was made, he had had to continue the East Pier another 300 feet, and it would no doubt have to be continued still further, in order to protect the harbour from the south-east current. Sir John Coode had given some valuable information with reference to the cost of concrete per yard; that information would be still more valuable if supplemented by the cost per yard of the wages of the divers, and of the diving-plant, in setting concrete blocks. The great difference, in the amount set aside for the depreciation in the dredgers at Newhaven, arose from the fact that the steam-hopper purchased from Mr. Simons cost £17,000, while Mr. Banister bought the "Hercules" at a sale at Portsmouth, for £800, and it did almost as much work as the steam-hopper. With regard to bag-making, considerable difficulty had at first been experienced in making them large-sized. He had a contract with a firm at Dundee, Mr. Banister.

r. Kinipple. such, as when reduced to the form of grout, especially thin grout, the materials, instead of remaining as a mixture, separated into layers, thus: 1st, or bottom layer, sand; 2nd, coarsely ground particles of cement; 3rd, cement, with setting properties greatly reduced; 4th, lime, &c., in a creamy condition separated from the cement through stirring in making up the grout. Failure was certain to follow the use of a mixture of sand and cement for grouting-purposes. The method he had always adopted, which he considered the proper one, was to employ a paste or very thick grout of neat cement, which would render success certain. It had been contended by Mr. Vernon-Harcourt, that the widths of breakwater, shown by some of the Figs. accompanying his Paper, were excessive. In the cases to which he referred the breakwaters were designed for a fishing-harbour, and the widths were necessary for quay room, the inner faces of the breakwater being vertical, or nearly so, for vessels to lie against. In such cases the hearting of the breakwater was intended to be of a very weak concrete, in fact almost a mass of dry stones, with just sufficient cement to bind them together. Alcoves were proposed to be constructed in the parapets of the breakwater, as shown by the dotted lines on the sketch, to serve as storage in which the fishermen's nets might be stowed. At Girvan Harbour, where a breakwater only was required without quay room, the width at top was 3 feet, and the experience of several winters had shown that in this case it was sufficient. Those methods of executing breakwaters proposed in his Paper, which might be termed novel, were only extensions somewhat modified, and upon a larger scale, of systems of executing work which he had carried out. In regard to their feasibility, he thought there could not be the slightest doubt, and it was to the advantage of the members of the profession, that the greatest number of practical ways in which concrete-work under water could be carried out, should be brought under their notice and placed clearly on record. He had referred to the expensive plant necessary for constructing works with large concrete blocks. In stating this he had more especially in view works of moderate extent, where a few thousand pounds only could be expended. In such cases the system of large blocks was not suitable, as the price of the plant would increase the cost so much, as to render the execution of the works prohibitory. In large works this objection of course did not apply, and for such he suggested the systems of construction by means of a travelling shield, or by caissons floated out by pontoons, as being both expeditious and economical. Mr. Giles was under a misapprehen-

sion in saying that he "had stated that it was not right to put concrete into water to set until it had been mixed for at least eight hours." Some experiments by Mr. D. Macalister, Assoc. M. Inst. C.E., at Garvel Park Dock Works, the results of which were mentioned in his Paper, had evidently been mistaken by Mr. Giles for his opinion as to the proper length of time to allow concrete to set before deposition. In practice, however, he adopted a much shorter period of time, namely, from two to five hours, depending on the proportion and quality of the cement, and the condition of the atmosphere; and he further advised the use of a small portion of quick-setting cement, such as "Orchard," "Medina," or "Roman," to reduce the time above-mentioned before deposition. From the remarks of Sir James Douglass, it would appear that he had misunderstood the conditions under which Mr. Kinipple had used plastic concrete. In Mr. Kinipple's experience, which was now considerable, he had obtained better results by using Portland cement concrete in a partially set or plastic form, than by any other method. He should be glad, at a future time, to give some examples of work executed with success upon the above system, and of other works executed with concrete mixed dry before deposition, and to show the difference. Mr. Kinipple.

Mr. J. KYLE, in reply upon the discussion, observed that as comparisons could not be justly drawn between works differently situated, it was his intention to confine his remarks to the questions arising from the subject of his Paper. As an instance of the falsity of such comparisons, he would take the case of Colombo. Many engineers would agree with Mr. Messent and Mr. Parkes that, as a work extended into deeper water, heavier seas were encountered, and that heavier works were therefore necessary. Now at Colombo, strange to say, the reverse was his experience. In the monsoon season of 1876–77, when the Titan was left out, some 400 feet from the Root, heavier seas struck the work than any experienced subsequently. In fact, at every season's advance the seas to be contended against were less, and after completion the Author found that the heaviest sea-stroke occurred from 300 to 1,300 feet from the Root end, in depths ranging from 18 to 24 feet at low-water. With regard to the question of the superiority of blocks over mass- or bag-work in the open sea, from a large and varied experience in the three methods, he believed the former to be the better. With blocks there was not that unsatisfactory feeling of uncertainty regarding the others. When a block was set in position, the builder knew what it was and where it was; whereas in the other methods Mr. Kyle.

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Mr. Strype. affect or disturb. He regarded the deposition of concrete in position, in this manner, as equivalent to the construction of prodigious blocks of concrete, of several thousand tons each, at once in their place, which were perfectly immovable and lasting; while the necessity to move, and correctly deposit, such masses, was entirely avoided, with the saving of the complicated and expensive special plant which all successful works adopting the block system had shown to be necessary.

Correspondence.

Mr. Barron. Mr. J. BARRON remarked that Mr. Kinipple's method of repairing the head of the South Pier at Wick, by covering the rubble base, above low-water, with a comparatively thin coating of cement-concrete, proved a failure, as the first storm had destroyed a great portion of the work. The description of shield proposed by Mr. Kinipple was, he thought, not adapted for the construction of sea-works, in a situation exposed to sudden storms, not to speak of the difficulty of constructing a roller-path, in the open sea, for a portable apparatus having so large an area of surface exposed to the force of the waves. The method adopted at Buckie Harbour[1] proved so successful, that, with the approval of Mr. A. M. Rendel, M. Inst. C.E., the Consulting Engineer, it had been adopted at Wick, and about 130 lineal feet of breakwater had now been successfully constructed in 15-foot depth of water at low-water of spring-tides, in the following manner: The foundations were cleared from all loose materials. A simple timber frame was erected, with posts placed about 4 feet apart, and covered with planking, which was lined with jute bagging. The concrete was brought direct from mixers in iron skips with open bottoms, each skip containing about 10 tons, and was deposited by a steam travelling derrick crane. By this method, blocks of 700 tons each could be cast in one day.

Mr. Brenan. Mr. G. WOULFE BRENAN, having been engaged on harbour and pier works on the west coast of Scotland during recent years, could testify to the advantage in the use of plastic concrete laid under water, as suggested by Mr. Kinipple. Wherever casing of any description was used, this method of laying the bulk of the concrete was at once safe and economical, and it permitted of a much larger area of work being dealt with than that laid in a

[1] Minutes of Proceedings Inst. C.E. vol. lxx. p. 350.

liquid state. In shooting liquid concrete under water through a hopper-case, or skip, there was always a loss of cement matrix from the sides of the bulk discharged, occasioned by sudden contact with the water; thus pockets were formed, and covered in, which had no adherence. This defect was overcome by the use of concrete in a semi-set state; but it was essential that it should be formed with a matured cement, and that the sand should be pebble shore sand, thoroughly cleaned by the sea, as the slow-setting process, which admitted of disturbance without injury, was, in his opinion, due to the presence of salt. The same result might be arrived at by the use of salt-water in mixing the concrete, but he preferred the first process. Having a good slow-setting cement, it was easy to determine by experiment how long the aggregate might be left to set before disturbance. He had built a heavily-loaded retaining-wall with rubble-stones and fine concrete, the latter being somewhat coarser than mortar, and handled precisely as lime-mortar would be, so that it was at times used twenty-four hours after mixing. This wall took nineteen days to set; after that time, however, it became quite firm. Since then he had adopted this practice in tidal-work with much advantage. He had always been struck with the increased cost of block-concrete over that laid in a fluid state in position, and he considered that only very special work should warrant the expenditure of constructing a whole breakwater of block-work. The liberal use also of monolithic concrete in sections of piers and breakwaters, except, of course, in well-known situations of great depth and exposure, was both wasteful and unskilful. Wherever possible, these structures, he thought, should be composed of concrete side-walls and hearting of good rubble, laid by hand on edge, and divided into sections with strong tie-walls of concrete. In these works weight was everything; and while the best block-concrete only weighed 3,500 lbs. per cubic yard, granite hearting weighed 4,080 lbs. the cubic yard; so that, provided a strong unbroken front to the sea could be secured, the weight was considerably increased, and the cost diminished, by the use of hearting in place of monolithic concrete. It was preferable in every way to widen the cross-section by rubble, rather than limit its weight, and therefore its stability, by a diminished section of solid concrete; but there was much benefit in capping the structure with concrete after settlement had ceased. He was not favourably impressed with the use of concrete in bags for the foundation of marine work. Bag-work had its distinct advantages and uses, but these necessitated its being laid in large sizes, requiring expensive plant. With bags of 40 tons

Mr. Brenan.

Mr. David Cunningham. strength of the concrete below low-water at Buckie (Cluny) Harbour, was greater than that which Mr. Willet had recently employed at Portsoy and Sandhaven; it showed no signs of weakness, and was, in his opinion, not likely to give way with any strains to which it might be subjected. In the concrete employed in the sea-faces of the breakwater and the West Pier above low-water, for a thickness of 5 feet, the proportion of cement has been as 1 in 7½, which was weaker than that employed by Mr. Willet, which was in the proportion of 1 in 6, and it occupied a much more exposed situation, the depth being from 10 to 12 feet at low-water. He had recently made a minute inspection of the harbour works at Buckie, and he found that a certain amount of damage had taken place. For instance, the outer ends, or heads of the breakwater and West Pier, where the sea struck heaviest, had been damaged to an aggregate area of about 28 superficial yards, and this had been faced up with sandstone courses. The whole of the remainder, with some trifling exceptions, where exposed to the sea, was in as good condition as ever, the plank-marks being still sharp and distinct. Now this work had been exposed to the sea for eight and a half years, and the average cost of repairs had been about £2 to £3 per annum. The question therefore arose, whether the employment of a concrete richer in cement than 1 in 7½ would have been justified. If 1 in 6 had been used, the probable cost of the additional cement required would have been some £1,200 or £1,500, which, reckoned at 5 per cent., would have involved a further annual outlay on the work of £60 to £75. He therefore considered it more judicious to risk a little in the construction of such works than to construct them so securely and so expensively as that not even the most exposed parts should ever give way. It was therefore somewhat questionable whether the proportion of 1 in 6, employed by Mr. Willet, was not, in the shallow situations occupied by the works of Portsoy and Sandhaven, unnecessarily strong and costly.

Besides the damage which had occurred to the outer sea-faces at Buckie Harbour, a good deal of damage had been done inside by the movement of the numerous fishing-boats, which, striking against the concrete, had frayed it and destroyed its texture. This kind of damage had occurred at two or three points along the walls, which had never been provided with wooden girders. But it had occurred more particularly along the north quay of the inner harbour, where the quay-wall was constructed of piers 4 feet thick, and arches of 20-feet span. The object of constructing this north quay in such a manner was chiefly to avoid the expense

Mr. David Cunningham.

which would have been otherwise entailed in founding the whole wall within tidal cofferdams. The material of the foundation was a sandstone rock, sloping about the angle of 45° downwards into the harbour. The excavation of the 20 lineal feet of rock under the arches was by the adoption of this design saved. But additionally, the amount of concrete needed for the quay was much less than an ordinary wall would have required, as might be seen from the section through this quay accompanying the Paper on Buckie Harbour Works. The result of these combined savings was that the quay cost about half as much as it would have otherwise cost. Here, then, there was a large margin of saving, out of which a little might be, if necessary, expended in the future for repairs. The question whether this quay should be fendered with timber had been discussed at the time of construction, and it was then decided that it would be time enough to go to the expense of fendering when it had been found necessary. It had now, after a period of eight and a half years, been found necessary, and the fendering was being executed. Meantime, however, the faces of the piers supporting the arches, which were of 1 in 5 concrete and 4 feet in thickness, had become, as might have been expected. from the movement of so many large fishing-boats (and the maximum lengths of these boats had increased from about 50 to 65 feet during the last ten years), frayed and broken, so as to necessitate their being repaired. The faces, then, were generally being built up with sandstone courses. The whole of the fraying had been repaired in this manner with stone, for it was unquestionable that stone would stand the action of this kind of damage better than concrete. He submitted that though repairs, apparently sometimes of a somewhat extended character, might be required in the course of years to the concrete of harbour works, this in itself was no evidence of failure either in design or in construction. And specially with regard to the design and construction of the works of Buckie (Cluny) Harbour, he affirmed now, in the light of the knowledge of the repairs which had been carried out since completion, that he knew no reason why any of the actual plans or proportions of construction should have been changed. Indeed, the experience of this one harbour (with some 40,000 square feet of concrete exposed to heavy seas), would appear to show that 1 in 7½ concrete was in such a position sufficiently strong. However, at pier-heads, where vessels entered and might touch, and where the seas swept round the convex faces with great impetuosity, carrying with them sometimes perhaps an auxiliary of gravel-stones, it might be better at first to employ stone instead of con-

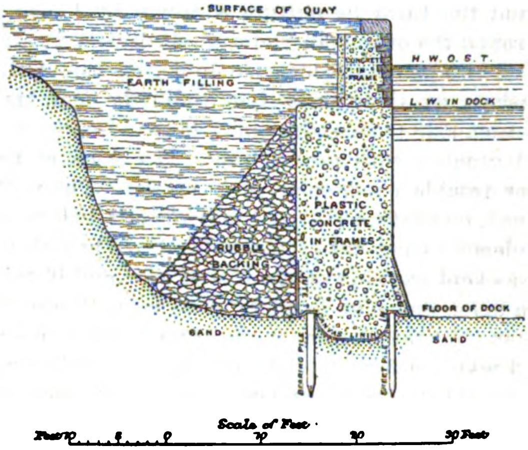
Mr. Russell. bottoms until it reached the height of 7 feet above the bottom of the curb. As little water as possible was used in mixing this concrete. After this had set for a week at least, the water was pumped out and the well was filled with 10 to 1 concrete in two layers. When the well was emptied of water, a slimy deposit 4 inches to 6 inches thick was found on the top of the 6 to 1 concrete at the bottom, which showed that in putting concrete in place through water, although it was perfectly still, care should be taken to clean the top of one layer before putting another on it. The deposit referred to would not set when exposed to the air. The spaces between the wells were about 1 foot 6 inches wide, and were filled from the level of the bottom of the basin upwards with 10 to 1 concrete passed through the water in boxes, having a capacity of 0·5 cubic yard, with hopper bottoms. The excavation was not carried lower, to avoid any chance of disturbing the foundations of the wells. Piles were driven before and behind the spaces to prevent shingle running in during excavation, or concrete running out before it had set. Those in front of the wall were ultimately cut off at the level of the bottom of the basin, and the others were left in place. A vertical recess 2 feet 6 inches wide by 1 foot 6 inches deep was left in the sides of each well wherever another well abutted on it, and the concrete in the two recesses and the space between them formed a large dowel. The recesses also facilitated the excavation, which was carried out with long-handled spades, by working the shingle from the piles to the space formed by these recesses, and by lifting it with a chain-grab. After a length of wells and the spaces between had been filled and left for some time, all inequalities were smoothed off at about low-water level with 6 to 1 concrete for its full width, and then the upper wall was constructed on it. This was 16 feet high, 11 feet 6 inches thick at low-water level, and 6 feet at the under side of the coping, and was constructed in five layers of 8 to 1 concrete. The coping was of granite 4 feet wide and 1 foot 6 inches deep. The cost of constructing and sinking the wells to the ordinary foundation-level, including excavation, was £65 4*s.* 6*d.* per lineal yard, and for the whole quay-wall £78 4*s.* 9*d.* per lineal yard. Some difficulty was experienced, when the sea was not still, in protecting the lower bed of concrete before it had set on the curbs on the foreshore. This was overcome by careful shuttering, which was not removed until the concrete was thoroughly set, and by covering up the top of the concrete with sacking, weighted with loose lumps of concrete, before the tide reached its

level. Another difficulty was the cracking of the sides of the wells, of which, however, there were only three serious cases. The cracks were always caused by the well getting hung up in going through ground which was softer at one side than the other. Every crack, however slight, was at once cramped with pieces of old rail, and grouted with neat cement, and after the first four wells had been sunk, iron-bond, as a precautionary measure, was used in their construction. This consisted of a double row of 3-inch by $\frac{3}{8}$-inch wrought-iron bars, which overlapped each other at the corners, where they were bent at right-angles for 9 inches vertically. These were inserted in the concrete 6 feet 6 inches, 14 feet 6 inches, and 24 feet above the bottom of the curb. Two of the serious cracks referred to were treated by the removal of 6 feet 6 inches of concrete from the wells, which were re-constructed, and the third by putting a 4-inch by 1-inch wrought-iron band round the outside of the well, flush with the face of the concrete, and two pairs of 2-inch wrought-iron bolts with 18-inch square washers at their ends longitudinally and transversely through it from side to side, the crack being cramped with pieces of rail and grouted with neat cement. In none of these cases was further trouble experienced from cracks. The wells on the foreshore had, on account of the loamy deposit before mentioned, a great tendency to get out of the vertical. When this occurred, the grab was kept working at the higher side, and if this was not sufficient, a diver was sent down to excavate with a long-handled rake under it. By these means it was comparatively easy to bring back a well which had tilted. In one case one end of a well was 4 feet 9 inches above the other, but when it had reached its foundation-level they were in proper position. Part of the basin had sloping sides at a batter of two to one. They were protected from high-water level to 7 feet 6 inches below low-water level, by an 18-inch layer of 10 to 1 concrete, the toe of which rested upon a 12-inch by 12-inch timber waling, which was attached to piles 12 inches square in sections 10 feet apart, driven about 10 feet into the ground upon a berm 3 feet wide. The slopes of the entrance channel, under the jetties were 2 to 1, protected by about 18 inches of 10 to 1 concrete in bags (seven to the cubic yard), which were passed through the water. Mr. Russell.

Mr. W. Smith observed, that the use of plastic concrete was commenced at Aberdeen Harbour in December 1881, and since then the wall (600 feet long) of Provost Jamieson's quay, and the quay-walls (900 feet long) enclosing the site of the graving-dock, Mr. Smith.

Mr. Smith. had been constructed on the method explained by Mr. Kinipple. The ends of the return walls of the graving-dock quays were exposed by the pumping out of the water from the site for the graving-dock, about nine months after the deposit of the plastic concrete, when the concrete was found to be tough and dense in texture, but not very hard. Provost Jamieson's quay-wall showed indications of a tendency to slip forward on the earth being filled in at the back, and to prevent this rubble stones were thrown into the water (Fig. 5) behind the wall until the stones next the wall appeared above water, allowing them to fall to a natural slope down to the bank.

Fig. 5.



The concrete was kept from two to four hours mixed before being broken up, and deposited in the water by skips opening at the bottom. It had to be broken up thoroughly, so as to flux together again in the water, when it formed a dense mass practically impervious to water. The final setting depended upon there being no addition made to the quantity of water absorbed in deposit. When the partly-set concrete was not thoroughly pulverized and refluxed by the water in deposit, the mass remained porous, and the water disintegrated the cement and prevented it from setting.

Plastic concrete took a long time to harden under water; if

exposed to the air it hardened rapidly as it dried, but this gave no indication of its ultimate consistency under water, which appeared to be equal to that of chalk. In foundations, jute canvas lining was found necessary to keep the Portland cement from being damaged by the clay and mud. The Aberdeen quay-wall, shown on Plate 1, Figs. 9 and 10, was the south enclosing wall of the graving-dock site, which was founded on a bottom of sandy clay, with a row of timber sheet-piles driven into the harbour-bottom in line with the edge of the cope, and a row of timber bearing-piles near the back of the wall, driven 4 feet apart from centre to centre. These precautions were insufficient to prevent the wall sliding on the clayey bottom, and rubble backing similar to that used at Provost Jamieson's quay was added. The stability of these quay-walls depended mainly upon the relief from lateral pressure afforded by the backing of granite rubble. The surface of the walls appeared perfectly durable in the Dock and Albert basin, where they were not exposed to stormy seas. The structures above water were built of Portland cement-concrete rubble, composed of 3 measures of granite chips, 2 of sand, 4 of stones, and 1 measure of Portland cement, faced with granite ashlar lining, and surmounted by a granite cope 3 feet by 1 foot 6 inches, in 4 feet to 8 feet lengths. The cost of the plastic concrete substructure of Provost Jamieson's quay-wall was 16*s.* 11¾*d.* per cubic yard, which included materials, labour, and framing, this part of the work having been executed without a contractor. The contractor's prices for the superstructure were for rubble concrete 14*s.* 5*d.* per cubic yard; granite ashlar lining, 22*s.* 6*d.* per square yard; granite cope, 3*s.* 6*d.* per cubic foot; cast-iron bollards, £14 10*s.* each; and wrought-iron mooring rings, 52*s.* 6*d.* each. The total cost of the quay-wall, pile foundations, rubble backing, and embankment, amounted to £8,241 11*s.* 11*d.*, about £13 14*s.* 9*d.* per lineal foot of quay-wall. The contractor's prices for the graving-dock quay-walls were, for plastic concrete in the substructure, 17*s.* per cubic yard, inclusive of materials, labour, framing, and plant; concrete rubble, 14*s.* per cubic yard; ashlar lining, 1*s.* 9*d.* per cubic foot; and granite cope, 3*s.* 3*d.* per cubic foot. The total cost of the graving-dock quay-walls was £8,844 15*s.* 11*d.*, or £9 16*s.* 6*d.* per lineal foot of quay-wall. Mr. Smith.

With reference to Mr. Willet's concluding remarks on the durability of concrete bag- and block-work at Aberdeen Harbour, the annual cost of repairs to the South Breakwater and the North Pier since the construction of the former and the extension of the latter had been :—

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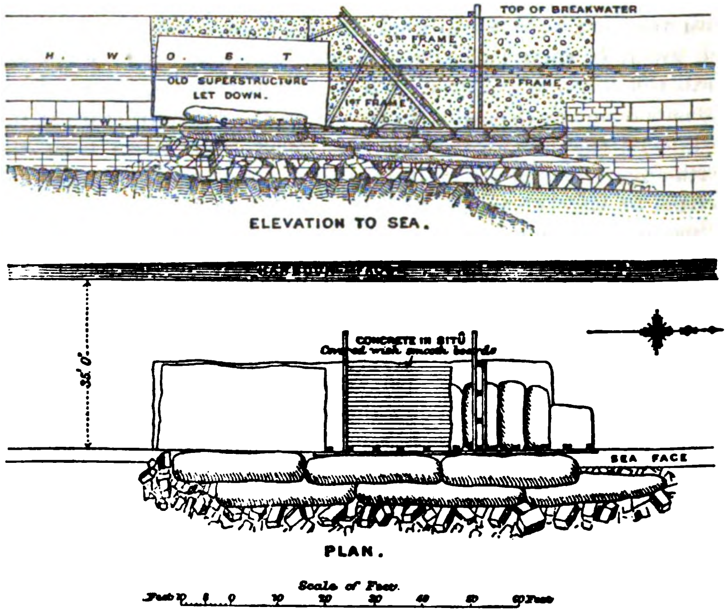
Mr. Smith. of concrete of 50 tons each, and an apron of Portland cement-concrete, 400 feet in length, was laid along the seaward face of the breakwater, covering the blocks and bags at low-water. The cost of these repairs and the formation of the apron during the year 1884 was £1,849. On the 20th of January, 1885, it was found that a length of 135 feet of the upper tiers of the apron of concrete in 50-ton bags, and 20 lineal feet of the concrete apron had been swept away. An additional length of 34 feet at the seaward end of the concrete apron had been undermined by the removal of the upper layer of bags and loose blocks. There was also a hole at

Figs. 10.



this point in the breakwater, extending from low-water level 6 feet downward, and penetrating inward to a crack pervious to air at the middle. The Commissioners thereupon consulted Mr. Philip J. Messent, M. Inst. C.E., who recommended them to "fill in the hollow space on the east side with rubble, built in Roman cement-concrete, protected during and after construction by old chains, made into bundles and placed in front of the repaired work" as a temporary expedient. For the permanent protection of the breakwater he advised lining the seaward face from the foundation upward with concrete blocks faced with granite ashlar,

the superstructure of concrete deposited in position to be faced with granite rubble. As a further protection against the undermining of the new work, he proposed to place an apron of 40-ton concrete blocks as headers on the foreshore, which should be roughly levelled to receive them. In the summer of 1885, the repairs under water were executed with concrete composed of gravel, sand, and Roman cement in the proportions of 2, 1 and 1, the superstructure where repaired being lined with granite ashlar in Roman cement. Four holes 3 inches in diameter were bored vertically down through the concrete superstructure from 18 to 20 feet, at intervals of 15 feet in a line along the middle of the breakwater, and 33 tons of grout composed of 1 measure of Portland cement to 1 measure of sand, were poured down to fill up the spaces between the blocks and the cavities in the foundation inaccessible from the sides. The execution of the repairs to the apron along the seaward face with Roman cement-concrete, and the exclusion of air from the body of the breakwater by liquid cement-grout had proved successful so far, this part of the breakwater having since needed no repairs. The repairs required this year had been comparatively trifling, consisting of two shallow cavities in the seaward face under the lighthouse, one at the seaward end, the other at the landward end of the large patch, shown by Fig. 5, executed in 1883. The cavities being partly above and partly below the level of low-water at spring-tides, the submerged parts were filled in by divers with small bags of strong Roman cement-concrete, and the upper parts were built at low-water with granite ashlar lining set in Roman cement. Two small holes were also found in the foundation blocks of the lighthouse tower on the harbour face of the breakwater. They were apparently due to excessive pressure on the edges of the blocks on that side of the tower, caused by the impact of seas on the tower, the blocks being split vertically across and the fragments scoured away. These holes were filled by the divers with Roman cement-concrete in small bags and neat Roman cement-grout. Mr. Smith.

The destructive influences bearing on the South Breakwater since its construction had been: 1st, the scour on the foundations of the seaward face by the seas coming from the north-east concentrated by deflection along the side of the breakwater; 2nd, the compression of air in the open joints of the blocks and in small cavities formed accidently by disintegration of the surface of the concrete, by the destruction of the piles passing through the concrete blocks by sea-worms, and by the subsidence of the blocks beneath the superstructure of homolithic concrete;

Mr. Smith. 3rd, the disintegration of the surface of the concrete by the chemical action of the salt-water on the Portland cement; 4th, excessive pressure on points of the concrete blocks, due to contact of the surfaces without mortar, splitting the blocks; 5th, the abrasion of the sides near the beach by stones, and the smashing of the roadway, parapets and stairs at the lighthouse tower by the water from spent waves falling off the tower. The most destructive force was that of compressed air, the other destructive influences being dangerous in the degree in which they laid the breakwater open to the compression of air by the waves. The peculiar construction of the South Breakwater rendered it very liable to injury from compressed air. The seas advancing from the north-east, as soon as they struck the breakwater, which lay north and south, became concentrated gradually as they ran along its seaward face, the difference of level between the crest and the trough of a wave increasing to about double at the middle of the breakwater. This increased the scouring effect, and at the same time the advancing wave flowed into crevices and compressed the air more powerfully with its increased head of pressure. Where the crevices communicated with vertical cracks in the monolithic concrete superstructure, the water was forced to a great height by the pressures of air in jets of spray from the roadway. During the destruction of the concrete repairs at the middle of the breakwater in August, 1883, a large mass of concrete was broken off the homolithic mass deposited a week previously, and lifted on to the roadway of the breakwater, whence it was swept away about ten hours later by the following tide. The deep cavity in the seaward face, 100 feet from the point of the breakwater (Figs. 9), was due to the blocks being blown out by compressed air. Those removed from their position in the harbour face at AA (Figs. 6 and 8), were blown out by the compressed air forced through the spaces between the sides of the blocks in the interior of the breakwater. The cracks indicated in the superstructure by the irregular black lines (Figs. 6 and 8), the greatest width of which was 1¼ inch, were due to the rupture of the bonding homoliths crossing the breakwater, and the separation of the two rows of homoliths forming the superstructure, by the force of the air compressed in the large cavern when suddenly covered in front by a wave. Probably the damage at this point AA was commenced, by the scouring away of the foundation of small bags resting on sand, allowing the concrete blocks to settle, sufficiently to relieve them of the weight of the superstructure, which held them in position. The extent of the injury was limited by the increased pressure of the superstructure brought to bear on

the remaining blocks at the ends of the cavern. The successful repair of the breakwater might be fairly attributed to the use of granite ashlar facing above water, Roman cement under water, and especially to grouting the landward 600 feet of the breakwater, so as to completely exclude air. The seaward portion of the breakwater was exposed to less concentrated forces, but in executing further repairs from time to time, the spaces between the blocks occasionally exposed to the air were grouted and plastered up. The Commissioners had postponed in the meantime the execution of the more costly permanent repair proposed by Mr. Messent. Mr. Smith.

In boring and blasting the concrete superstructure of the South Breakwater, the concrete was found to be sufficiently hard; a greater proportion of cement would not have increased its hardness. Where concrete was exposed while soft to the action of water, tending to waste the cement and keeping it from setting hard, it was advantageous to increase the proportion of Portland cement; but when the concrete was mixed and deposited above water, and the blocks were kept dry while setting, any increase of the proportion of cement beyond what was necessary to form a matrix for the grains of sand and coat the gravel was waste, for the sand and gravel were harder materials than the set cement, which latter in excess would not increase the hardness of concrete. It would, however, increase the density of the concrete which in sea works was of great importance, the porous nature of concrete making it subject to rapid disintegration by compressed air when the outer skin of plaster had been broken. To gain sufficient density to withstand permanently the action of the sea, the proportion of cement would have to be increased to an extent that would cover the extra cost of a facing of granite, which was preferable to any concrete. No fault could justly be found with the proportions or quality of the concrete of the South Breakwater. It was only by careful collation of the experience gained in the maintenance of this and similar works, exposed to the unbroken force of storms, that a satisfactory method of construction for breakwaters would be arrived at. The North Pier was not a breakwater but a jetty, projecting from the hollow of the bay, protected from the force of north-easterly seas by an extensive shoal, and from the south-east by the South Breakwater. It was not certain that the South Breakwater would have stood better if constructed in the same way as the North Pier, the breakwater being in a much more exposed position than the pier.

The provision for the prevention of irregular cracks in continuous concrete walls, owing to variations of temperature, by

Mr. Smith. means of cross-panelling adopted at Wicklow Harbour, had been in use at Aberdeen during the last six years in the formation of concrete footpaths. At intervals of 6 or 8 feet, strips of lathing boards $\frac{3}{8}$ inch thick were inserted and left permanently in the pavement, the timber yielding to compression by the expansion of the concrete at high temperatures. This provision was inadmissible, however, in the formation of a concrete graving-dock at Aberdeen, which was built on an alluvial deposit of sand, clay, and gravel, subjecting the concrete-work of the dock bottom to hydraulic pressure every time the dock was emptied. The contraction of the concrete floor by frost during the night was apparent by the damp showing at the joints of the concrete monoliths, and at the entrance by fine irregular cracks in the plaster. Part of the plaster of the dock floor had to be taken up and relaid, owing to want of homogeneity with the concrete bottom, a very thin layer of mud forming between the plaster and the concrete, 6 inches under the surface. The body of the plaster was made of machine-crushed granite and Portland cement, in the proportions of 4 parts of the former to 1 part of the latter. The presence of the feldspar in the crushed granite caused the concrete to become extremely hard while kept dry, but soaking with salt-water appeared to cause the Portland cement gradually to unite with the feldspar, separating the chalk in the cement from the clay, and forming a layer of white mud between the pavement and the concrete. In relaying the defective parts, perfect adhesion between the new plaster and the concrete bottom was ensured, by washing the surface of the concrete with a strong solution of carbonate of soda.

r. Spencer. Mr. H. G. Hammond Spencer having, at the suggestion of Mr. Kinipple, carried out some experiments in Jersey, in making concrete blocks in deep water by the use of pipes, thought that some further details of the experiments in question might be of interest. The cement used was that made by Messrs. Peters Brothers, of Rochester, which had been employed in the harbour works at St. Helier for some years, and was not very quick setting. In the experiment in a depth of 60 feet of water, and in the open sea, gas-piping $1\frac{1}{2}$ inch in inside diameter was screwed together as the box of broken stone was being lowered. A length of 4 feet at the bottom was of zinc, perforated with $\frac{3}{4}$-inch holes for a length of 12 inches at the extremity, in order to facilitate the exit of the grout. This use of zinc pipe was an unfortunate one, as it bent, and partly broke across, at the top of the box, before the experiment was concluded. The barge having been anchored, the grout

was made in a tub, and at once poured down the pipe by a funnel, the air in the pipe being driven out with a report like the discharge of a pistol. Before the calculated quantity of grout had been poured down, he was led to believe that something had happened to the pipe, but what that was it was impossible to say. The pouring was therefore completed, notwithstanding the impression that no further good would result. The range of the tide in Jersey being about 40 feet, its run was so strong that it was not astonishing that the zinc pipe gave out under the strain caused by the tide and the weight of the gas-piping. When the box had been lowered on to the bottom, the pipe was hauled up, and it was then found that the zinc pipe was bent at right-angles and split open. On account of stormy weather the box could only be lifted at the end of four weeks, and it was then found, as expected, that only a little more than one-half had been filled with the grout. That half was, however, very satisfactory. Since then he had substituted for the zinc pipe one of wrought-iron, perforated in a similar manner; and, although he had not yet had an opportunity of making a further experiment in deep water, he entertained no doubt of its proving a success, as the partial failure on the first occasion was undoubtedly due to the giving out of the zinc pipe. After the experiment described above, the weather was so stormy that it was impossible to repeat it in the open sea; but wishing to observe the action of the flow of the grout, he procured a wrought-iron tank 4 feet by 3 feet, and 3 feet high, into which, when filled with sea-water, were lowered two boxes of broken stone, open at the top, each 12 inches by 6 inches by 6 inches. A tin pipe, 1 inch in diameter and 4 feet long, was inserted in the broken stone of each box in turn, and filled up, the first with grout about as thick as pease-soup, and the second with grout as thick as would run. In both cases the result was the same, the loud crack of the air driven out, soon followed by the appearance of the grout above the stones, when the pouring was stopped. Seven days later the boxes were taken out, and the resulting blocks of concrete, having been found set hard and sound outwardly, were allowed to dry for three days, and when split both presented the same appearance, there not being the smallest space unfilled by cement. The boxes were of rough sawn wood, and the outside of the blocks bore a perfect impression of the wood, the knots being reproduced in a most beautiful manner. As he wished to ascertain whether the cement was materially weakened by being used in the form of grout, he prepared a series of test briquettes, of the usual form, of each of the two sorts of grout mentioned above, and also of cement Mr. Spencer.

Mr. Spencer. made up in the usual mode for testing. These briquettes, after being immersed for seven days, were tested in the usual manner in one of Michele's machines. The average results were that the grout briquettes broke at 650 lbs., and the cement briquettes at 725 lbs. per section of $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch. From this it would seem that the cement did not seriously suffer by being made into grout, and doubtless if a longer time had elapsed before testing, the difference would have been less. He believed that the system of making concrete by means of pipes was one which could be employed with ease and economy in many cases.

Mr. Stevenson. Mr. David Alan Stevenson could not concur with the views expressed by Mr. Kinipple as to the advisability of using cement-concrete which had been allowed to half-set before being put in position, nor did he think the methods of construction proposed would prove successful. The construction of engineering works generally, and marine works in particular, had been greatly simplified by the employment of Portland cement-concrete in the form of blocks, in bags, and in position. His firm, as Engineers to the Commissioners of Northern Lighthouses, to the Fishery Board of Scotland, and to various harbour authorities, had constructed numerous marine works of that material, and the success which had attended them proved, he thought, the suitability of this material for such purposes, not only as regarded the facility with which the works could be executed, but their durability after completion. It must not be forgotten, however, that success depended on the choice of proper proportions, the use of good cement, clean sharp sand, clean water, and careful mixing. Failures such as had occurred at Fraserburgh, as detailed in Mr. Willet's Paper and elsewhere, were not to be attributed to the use of concrete, but to some defect in its quality. Messrs. Stevenson had acted as Consulting Engineers for the Sandhaven Harbour works, and the account given of them might be taken as a fair sample of the general construction of pier adopted at numerous fishing-harbours on the coast of Scotland with uniform success. Where the concrete, made of 1 part of cement to 6 or 7 parts of stone, &c., was deposited in frames, its strength was ample, and large pieces of rubble-stone could, in addition, be safely dropped into the frames as the concrete was brought up, provided they were not allowed to touch one another, or approach nearer the face of quay than 9 inches. This materially cheapened the work per cubic yard, and in no way interfered with the strength of the work. When the concrete had to be deposited under water, bags were employed, and the proportion of cement to stones, &c., was as a rule 1 to 5. The following was the method of

testing the strength of cement which his firm frequently inserted in specifications, where the works were small and the expense of providing a testing-machine a consideration:—"The cement is to be made into small blocks, 1 inch square and 8 inches long. After being made, these blocks are to be immersed in water for seven days, and then tested by being placed on two supports, 6 inches apart, when they must stand the transverse strain produced by a weight of 75 lbs. placed in the centre." Mr. Stevenson

Mr. Bindon B. Stoney remarked that the cost of floating-plant to lay large blocks need not deter engineers from adopting it, for the cost of the floating-sheers with its chains and machinery complete, which had been in use for sixteen years, lifting 350-ton blocks in Dublin, was less than £19,000,[1] and the cost of a barge and machinery capable of lifting 100- to 120-ton blocks need not exceed £5,000 to £6,000. On the other hand, no piles, panels, staging, rails, Titans, or similar appliances, were required on the wall or pier under construction; and, as compared with concrete lowered through water, the engineer had the satisfaction of seeing the blocks before they were laid, and testing their quality by the process of lifting, for under scarcely any circumstances would they be liable in the structure to so intense a pressure per square foot as they were at the time of lifting from the bearing pressure of the suspender bars. For example, the 350-ton blocks in Dublin were lifted within ten or twelve weeks after construction at four points, the bearing pressure on which was about 33 tons per square foot. In place of the small dove-tailed blocks adopted by Mr. Kinipple for the face of concrete walls above low-water, Mr. Stoney had been in the habit of using blocks weighing nearly 3 tons each, and 3 feet 6 inches high. These brought the work rapidly above the tide. The faces of the joints were pointed with quick-setting Medina or Orchard cement, and the joints were then grouted with Portland cement, and the concrete hearting was filled in in the ordinary plastic condition with displacement stones where desirable. For small works in out-of-the-way places, he preferred hard bricks laid in quick-setting cement for the face-work, backed up as before with concrete, as bricks could be readily handled by men in a boat, or in places where heavy plant was not feasible. Many years ago Mr. Stoney built a concrete sea-wall 4,550 feet long in the usual manner, the foundations being laid inside a trench the sides of which were sheet-piled with 3-inch planks, and the concrete above low-water was rammed inside panels. A portion of Mr. Stoney.

[1] Minutes of Proceedings Inst. C.E. vol. xxxvii. p. 363.

Mr. Stoney. the concrete was, for the purpose of experiment, mixed dry and then lowered through the water between the panels. This portion of the wall was honey-combed, and not nearly so close as that formed of concrete tempered with water in the usual way before putting it in place. Another experiment was made by mixing concrete dry and filling a box with it. Water was then added, but the concrete when set was full of cavities. This result might have been anticipated from the fact that a mixture of loose dry gravel and sand often reduced 15 to 20 per cent. in volume when tempered with water, and so did dry concrete. When lowering concrete in boxes through water, it was desirable to use as large quantities in each box as possible, to prevent the cement from being washed out of the mass. The concrete inside the caissons of the piers of O'Connell bridge was made in the proportion of 1 part of cement to 3 parts of ballast and 1 part of broken limestone. This was lowered through a depth of from 20 to 30 feet of water in an iron box, with a hopper-door in the bottom, each charge containing 10 tons of concrete; and in another work in Dublin harbour large quantities of concrete, in the proportion of 1 part of cement to 8 parts of ballast, were lowered in a box holding 40 tons, through a depth of 42 feet of water, into trenches excavated in soft clay, to form artificial foundations for a lofty quay-wall. On examining this concrete with a large diving-bell, which was used for levelling the surface, it was found exceedingly close and compact. The cost of this artificial foundation was about 17*s.* per cubic yard. One of the objections to lowering concrete in boxes through water, which, however, was seldom alluded to, was the tendency of the finest portions of the cement to separate and form layers of chalky matter, called "laitance" by the French, which had the consistency of hard cheese, and probably never became indurated. Blocks formed in the air and sack-blocks were free from these soft layers, and so far had an advantage over concrete passed in boxes through water. Mr. Kyle's description of Colombo harbour works was an exceedingly valuable contribution, and contained a great number of interesting details. Its value, however, would be increased if the Author would state what was the advantage of blocks built in a sloping direction over those laid with vertical joints. The sloping system had been adopted early in the century, and probably for the first time in any important work, at Ardrossan harbour, where the pier under low-water was formed of three tiers of large stones varying from 6 to 10 feet long, and 3 to 4 feet wide, laid in a sloping direction across the length of the pier. The sloping system

was afterwards developed on a large scale by Mr. Parkes about fourteen years ago at Kurrachee, where the Manora Breakwater was constructed of 27-ton blocks laid on top of a rubble mound. A curious result occurred at one part of this breakwater, due to the slope of the blocks. Mr. Parkes, in a report dated the 28th of February, 1872, after describing the dislodgment by storms of some of the blocks, went on to state, "None of the blocks on the sea side have been forced out in this way; but another result, probably also due to vibration, has been produced. The two rows of blocks were originally laid so that their front faces were in the same plane or flush. After the monsoon, it was found that the last block on the seaward side had fallen back about 9 inches from the line of that on the harbour side, and this continued, though gradually decreasing in amount, to near the shore. The slight movement of the blocks among themselves had rubbed off some of the little inequalities which had prevented adjoining surfaces from fitting quite closely when first laid, and so enabled each block to fall back upon the one behind it to an infinitesimal extent in any one case, but amounting in the aggregate to 9 inches." Probably the joggles used at Colombo would prevent movements such as those which occurred at Kurrachee; but they would not prevent settlement of the mound, in which case the joggles would probably be ruptured, or if not, they would cause the blocks locally to bridge over the hollow formed by the mound settling. Another matter required elucidation, that was the effect of water and air impounded by waves between the joints of the blocks, tending to blow up the concrete capping which was only 4 feet thick at the centre and less at the sides. This explosive action might frequently be observed in harbours in the United Kingdom, where the impounded air and water often blew up the surface and drove out stones on the inner or harbour side of a pier. As the Colombo Breakwater must be submerged in severe storms, it would also be interesting to know how the shelter inside was affected by this, or whether the waves passing over the breakwater caused much disturbance inside. Mr. Stoney.

Mr. B. H. THWAITE remarked, that although the application of concrete in bags had decided advantages, nevertheless it was questionable whether the foundation of a wall, so formed, would be of a thoroughly homogeneous and sound character; the fibre of the bags would certainly prevent chemical action of crystallization between each individual mass of concrete so applied, and when once disintegration had set in, the action would be more or less rapid and complete. Mr. Thwaite.

Mr. Kinipple. Mr. W. R. Kinipple, in reply to the correspondence, observed with respect to the head of the South Pier at Wick, that there was no failure of his method of repairing that pier-head; but during a gale, whilst the works were being executed, part of the base of the old rubble-work was washed out, whereby a portion of the concrete-work in progress was undermined and gave way, and it was evidently to this matter that Mr. Barron referred. It, however, had no connection with the method of depositing the concrete, or the soundness of the concrete. The washing out of the rubble was due to the toe or bottom of the slope being unprotected. He had recommended a protection of sheet-piling to guard against this danger, but it was not carried out at the time, although he believed it had been subsequently adopted. The damage done during that storm was repaired by concrete, deposited in the same manner as in the first instance, and the work had remained since perfectly sound. The success of the method adopted at Wick could not be better shown, than by the fact that on one occasion a block of about 60 tons weight had been formed in position on the nose of the breakwater, at 2 feet above low-water, and within twenty hours afterwards it resisted successfully a most severe storm. He did not know any other method than that pursued at Wick, whereby the work (which consisted in the covering up and rendering secure a mound of rubble which was being washed into the harbour) could have been satisfactorily executed without plant, at a small cost. It had been contended by Mr. Cay, that experiments which he had made showed that the plastic system of executing concrete-work was not practical. It would have been much more satisfactory if Mr. Cay had given details of his experiments, and his reasons for arriving at that conclusion. Mr. Kinipple had successfully used plastic concrete in works at Greenock, Girvan, Wick and Quebec, 8,000 lineal feet of quay-wall and piers having been thus formed. The soft nature of the work constructed of plastic concrete by Mr. Smith at Aberdeen, was, he thought, due to the nature of the cement used, and not to its having been employed in a plastic condition. The quality and condition of the cement, for work to be constructed under water, probably did not receive sufficient attention from engineers. This he could not illustrate more strongly than by considering the two following cases, namely, first, concrete formed of new Portland cement, hot, over-limed in order to render it quick-setting, and having a tensile strain at the end of seven days of about 500 lbs. per square inch, mixed with 6 parts of sand and ballast to 1 part of cement, and deposited (under water) immediately after mixture. In a week or so the concrete would have the

Mr. Kinipple. appearance of being thoroughly sound, but at the end of fifteen months or of two years it would probably be broken up by expansion of the mass, due to the slacking of the excess of lime contained in the cement. In the second case, very finely-ground cement, not overlimed, having a tensile strength of 300 lbs. per square inch, thoroughly slaked in air for a couple of months, mixed as in the first case with 6 parts of sand and ballast to 1 part of cement, the mixture slightly damped and allowed to set from two to five hours (according to the state of the weather), with the addition of a small portion of quick-setting cement, such as Orchard, Medina, or Roman, immediately before placing it in skips and depositing it under water. Under these circumstances a perfectly sound concrete would be obtained, free from any risk of subsequent disintegration. The cement required for concrete-work under water was one, which, in addition to eminently hydraulic qualities, and freedom from disintegrating constituents such as excess of lime, magnesia, &c., should also possess what might be termed unctuous properties, or the power of preventing the separation of the particles of the mixture forming the concrete, and of resisting a current of water during deposition under water. He believed the manufacture of a cement such as this to be possible, although at present he was not aware of any in the market. An approximation to it was obtained by adding to the concrete, immediately before deposition, a small quantity of Orchard, Medina, or Roman cement. With the possession of cement having the properties mentioned, monolithic breakwaters could be rapidly and cheaply constructed, the portions below low-water by the aid of ordinary hopper-barges, conveying from mixing platforms at a convenient position on shore loads of, say, 500 tons of concrete, and depositing the concrete in the work, whilst the portions below low-water could be constructed within timber frames in the usual way. It was evident, in breakwaters so constructed, that there would be almost no limit to the rate of progress, as work might be carried on simultaneously over nearly the whole line of breakwater. A feature of concrete-work under water, which ought not to be left out of sight, was the reduced strength of the work so executed, as compared with concrete of the same proportions of constituents executed out of water. The reduction of strength in many cases with quick-setting cement was from 50 to 70 per cent. The tendency of the profession, for a number of years past, would seem to be in the direction of constructing breakwaters on the monolithic system from foundation to cope. He was glad to observe this, especially as he had held that

Mr. Kinipple. opinion strongly for the last thirty years, and had constantly advocated it.

Mr. Kyle. Mr. J. Kyle, in reply to the correspondence, noticed that considerable importance had correctly been attached to the proper proportions for concrete in works above, and under, water, especially in the manufacture of blocks and the deposition of mass-work. He was of opinion that upon the relative proportions of sand and cement mixed with the least quantity of water, and upon the relative proportions of this mixture with the stone, both being allowed to set after mixing without disturbance, the ultimate success and strength of the block or mass depended. His experience proved that 2 parts of sand to 1 part of cement was the strongest and cheapest average proportion for all block-work above water, and that this proportion, added to 6 parts of screened 3½-inch broken stone, exactly filled the interstices of the latter. Reference had already been made to a sample of this mixture, exhibited at Melbourne, and he would further add that this block was split, hewed and chisel-dressed to an arris, equal to that produced on the hardest sandstone, without dislodging the chips or disintegrating the mass. Concrete of this quality would show less disposition to abrade than any sandstone, and it was sufficient of itself to sustain a face almost equal to that of granite, provided the chips were of granite.

On reference to the results of other works, he thought that if stronger and weaker mixtures than this failed, the medium used at Colombo must have been the happy one. By experiment, no cement would carry more sand than in the proportion of 2 to 1, and give strength and satisfaction in the long run. With a lower proportion of cement the mixture lost proportionately, in cohesive value, more than the value of the cement saved. The proper quantity of 2 to 1 required, would be equivalent to the volume, by test, of the interstices of the stone, and that again depended upon the gauge used. No portion of this hand-broken or machine-crushed stone should have smaller particles than the size of small horse-beans or peas, and all below this size should be removed by a screen. In every case cement block-concrete, having a higher or lower strength, would be unnecessarily costly or weak. In proportioning sand and cement, care should be taken that the interstices between the sand were filled with cement. In the case of the mixture of 4 to 1 of sand and cement at Aberdeen, this could not have been so.

In reply to Sir Charles Hartley, he would observe that the original design referred to had not been fully carried out. Sir John Coode had, in 1872, several plans laid before him by the

Government, which had been based upon information collected in the Colony by the authorities, relative to the materials, site of work, winds and waves, &c., and his opinion, with a plan and estimate, was given upon the same basis. During Mr. Kyle's three months' preliminary visit in 1873, when he collected detailed information for carrying out the works, he, without the experience of several monsoons, could not ascertain anything further as regarded the waves. After the works had been started, and several monsoons had passed over, he proved, in his monthly reports, that the height of wave given Sir John Coode in 1872 as 9 feet in a very heavy sea, should have been 15 feet, and that such seas, after striking the wall, rose in spray 120 feet above sea-level, and enveloped the structure from the Root to pier-head, thus preventing the scheme of bringing the vessels alongside from being carried out. In addition to this, after a few years' experience, it was found that the port traffic had so increased, as to cause the Resident Engineer to report, that the scheme as originally designed, would not accommodate the increased traffic. To have extended the double-wall system to meet these demands, would have been beyond the means of the Colony, hence the resolve to modify the breakwater section to its present extended and less costly form. The first tier of mooring buoys were 300 feet from, and parallel to, the breakwater. In the heaviest weather the Resident Engineer had tested the effect of the seas within this area. Running a boat inside, he found two series of waves, at different intervals, striking the wall. The first series struck with a dull ponderous thud, and, leaping 30 feet above the wall in green water, fell on the wall without spray. The second was of a more angry description, and, after striking, bounded into the air, rising 120 feet above sea-level. At a distance of 50 feet inside the wall, a wave of 3 feet was raised by the falling water, diminishing to a few inches at 200 feet, while the spray itself was heavy enough to prevent a boat approaching within 100 feet of the wall. From the outset, the seaward berms showed no signs of weakness, nor cause for supposing that the rubble would be swept away, and the bag-work apron was merely overlaid as an additional security against such a contingency. The signs of weakness, which indicated the inadequacy of the sea-wall to sustain unaided the thrust of the waves, had been given in his Paper, where it was stated the sea drove in the scar-end 15 inches, pivoting on a point 150 feet landwards, &c. The core and main body of the rubble mound was composed of hand rubble up to pieces weighing 5 cwt. each, while two-thirds of the seaward berms consisted of pieces from 1½ ton to 3 tons each, Mr. Kyle.

Mr. Kyle. pitched in, by tip-wagons direct from the wall, where they remained until the sea clawed them down to the line fixed for the reception of the bags of concrete. The depth to which the foundations of such works as this one, on sandy bottoms, should be taken, depended upon the fetch, exposure to wind and depth of water, and it might vary from 20 to 24 feet at low-water. Foundations in less than, and up to, a depth of 20 feet should be protected from scour either by large rubble, by concrete blocks, or by bags; while in water above 24 feet deep rubble in 3-ton pieces would be sufficient with a long fetch. There were two important forces at work, the first force was mainly exerted against the superstructure above water, and the second against the substructure under water; the former was calculable, but the other was not. The forces generated by a new work under water, such as sand movements, caused by diverted oceanic currents, must be guarded against, otherwise the berms would be undermined, and disaster would surely follow. Keeping the foundations well down would avert the one, but not the other, and no work on sand would escape ultimate destruction unless the toe of the berm in shallow water was protected. Without a northern arm, no further improvements could be made in the harbour; nor would a jetty alongside, graving, slip, or floating dock be practicable until such time as this work was carried out. The gross sum of £317,583 was for the breakwater pier, including pier-head, landing-pier, lighthouse, capping, &c.; while the sum of £247,313 was for the sloping blocks alone in the breakwater pier, exclusive of the other items. The joggle system adopted at Colombo, to prevent cross-movement between each slice or sloping course, was open to improvement.

Another most important point raised, was that of the action of compressed air on the Colombo and other works. He had given this his careful consideration and study during monsoon weather, and concluded that the solid-wall sloping-bond principle in this constituted another point of advantage over ordinary block in horizontal course and mass-work, with or without hearting. During the earlier stages of the work, he noted the force with which the compressed air was ejected from joints on the upper surface during the prevalence of heavy seas. Having to protect the Titan road from being washed away, he found it necessary to joint up all the blocks above water with cement-mortar, and to deposit mass concrete between the rail timbers in a layer 1½ foot thick over all the intervening surface. This skin and joint-work followed the progressing wall, and although seven or eight monsoon seasons had

elapsed, no blow up worthy of note had occurred in any place. From the nature of the design, the blocks were chamfered 3½ inches on the corners, and as the longitudinal sloping beds were level in the transverse direction, the chamfer formed a through free channel, or safety-valve, at each low-water course joint, for the rushing air, which found an easy exit through the wall at the harbour side, thus relieving the temporary skin of any pressure that might then have blown it up, as also the present heavier or permanent capping. There were times and seasons when the breakwater, as viewed from the Resident Engineer's office, was completely submerged from the Root to pier-head, yet up till now no destructive effects had been experienced, although the first season's work had been completed in 1876–77. Mr. Kyle.

In the latest reports from the now Resident Engineer in charge, Mr. John Kyle, jun., Stud. Inst. C.E., the usual surveys of the foundations and superstructure after the monsoon had been made, and he found no perceptible change in the levels or in any portion of the work.

Mr. J. Willet remarked, that in his Paper on the Fishing-boat Harbours on the north-east coast of Scotland, it was stated shortly how powers to construct the Fraserburgh Breakwater were obtained, at the time when he was acting as Engineer to the Commissioners. After the loan was obtained, a Resident Engineer was required, and Mr. Bostock was appointed, and Mr. Willet's immediate connection with the harbour thereupon ceased. It had, however, been arranged that he should write the Paper on Fraserburgh Harbour, and, having to procure much of the necessary information from others, he was placed somewhat at a disadvantage in the discussion and correspondence, as he had not had the opportunity of personally superintending the works while in progress. For the Commissioners of a small harbour to have risked raising the sum of £60,000 without any aid from the Government or other source, and on the security of the harbour rates as they existed at the time, might appear to have been rather a bold undertaking; but the case was urgent. The number of boats frequenting the harbour was steadily increasing, and before the works were completed they exceeded seven hundred manned by nearly five thousand men. When the weather was favourable most, if not the whole, of this fleet proceeded to the fishing-grounds during one tide. On the north-east coast of Scotland storms from the north suddenly sprang up and caused the fishermen on the fishing-grounds to make haste homewards for shelter; consequently, when the crowd of boats ap- Mr. Willet.

Mr. Willet. proached the harbour, each one endeavouring to get through the narrow unsheltered entrances (Plate 6, Fig. 1) with as much speed as possible, a "block up" was apt to ensue. Such a "block up" once occurred at Peterhead and caused great loss of life and property. Without the shelter now afforded, a like disaster might have taken place at Fraserburgh with more serious results, and it was this consideration that mainly induced the Commissioners to take such a bold step. Apart, however, from the shelter afforded by it, the breakwater was now used during the busy season as a landing-quay for herring-boats and steamers; so that its erection had materially contributed to the increase of revenue at the port. He had given details of some damage done to the works during the storm of March 1883, more for the purpose of showing to what forces the breakwater was exposed during north-east gales, than to throw any doubts on the stability of the structure, which, as a breakwater, was now as strong as when newly finished, and had fully answered its purpose, namely, to afford sufficient shelter to the existing harbours. The storm of 1883 raised such large waves that part of the glass in the lighthouse, 72 feet above the level of high-water mark, was broken by them; but as regarded the concrete, a few of the weakest points only were touched. The damage done had been repaired at no great cost, only 1¾ per cent. of the total outlay. In a work which had to be pushed forward during favourable weather with the utmost despatch, there was the risk of unfavourable circumstances occurring to prevent the whole being made uniformly perfect, even with the best materials and most careful supervision. At all the points damaged, the concrete was deposited when there was a considerable swell or motion in the sea. The repairs executed during the past three years had stood well, and had arrested any further inroads into the concrete. Plate 6, Fig. 3, showed the greatest breach, and it would be seen that the foundations (50-ton bags) must have given way first; whether this was caused by the bags not adhering so closely together as to prevent air getting between them during the recoil of the waves from the perpendicular wall, or by their being damaged after being deposited by the keels of fishing-boats, could not now be determined. It was proper to state that the best of the materials, such as sand and gravel, became exhausted before the breakwater was completed, and the Resident Engineer was compelled to use sand from the sea-beach, nothing else being available within reasonable distance. In this connection he desired to mention that the deposit of concrete in bags by a hopper-barge adopted at Fraser-

burgh, was, he believed, the invention of Mr. Dyce Cay when he was in Aberdeen. Mr. Willet.

The Sandhaven Harbour works had been described more for the purpose of showing what could be done by unskilled labour, without the aid of expensive plant, than from any peculiarity in the structures. The greater part of the breakwater was founded on rock, and the force of the seas was broken, to some extent, before they reached the outer wall, by a mass of outlying rocks. The north-west corner, however, had to withstand the full force of northerly gales, and the outer wall there had been strengthened. No damage had been done to any part of the works. Care was taken to provide the best materials, the greater part of the sand being washed before mixing.

The Portsoy works were given as a specimen of a series of harbours which he had erected during the past twelve years. The place was greatly exposed, and nothing less than one monolithic mass of concrete could have been safe. As the means at the disposal of those interested in the smaller harbours along the east coast of Scotland were limited, and as there was usually no natural shelter, the greatest precaution had to be taken to ensure that the works were so constructed, as to entail the smallest possible expenditure on future repairs. Carefully-prepared cement-concrete, when once safely deposited, had proved to be the best material. The contractor's price for the concrete-work at Portsoy was 15*s.* per cubic yard, but part of the materials used was from rock-cutting from the deepening of the harbour, for which a full excavation price was allowed.

The 50-ton bags of concrete, as first introduced at Aberdeen, had proved the best and most expeditious method yet tried for withstanding the scour due to the recoil of waves from a perpendicular wall. The damage to Fraserburgh Breakwater (Plate 6, Fig. 3), was most likely due to the bags having been cut by the keels of boats, before they were covered by the upper mass. The proportion of cement to gravel and sand would vary with the exposure. The difficulty of making perfectly air-tight joints, even with the bag system was great, and the compressed air driven into these joints was the most destructive power which engineers employed on the east coast had to contend with. It had been stated that he attributed the damage to Fraserburgh Harbour to the composition of the concrete, it being so poor as to contain only 1 part of cement to 9 parts of sand and gravel. Now, although that small proportion of cement no doubt contributed to the damage, it certainly did not altogether cause it; and there was

Mr. Willet. nothing in his Paper to lead to that supposition. Further, the accuracy of his remarks, on the inadequacy of the plans hitherto tried along the north-east coast of Scotland, for concrete-work below low-water had been contested, and the employment of 1 in 7½ concrete, or concrete even less rich, had been justified. In reference to these points, he might remark that one of the objects of his Paper, was to elicit the opinions and experience of members who had designed and constructed fishing-boat harbours; and it was satisfactory, among the many valuable opinions expressed, to learn, on the authority of the Consulting Engineer of Buckie Harbour, Mr. D. Cunningham, that the works there had sustained little damage since their completion. Mr. Willet, therefore, hoped that Buckie Harbour was an exception to his general remarks on the north-east coast harbours. The success there appeared to have been due to the manner of depositing the concrete by skips into a simple timber frame, as explained by Mr. Barron, and to the use of a greater proportion of cement below low-water than at Sandhaven and Portsoy. What this proportion was Mr. Cunningham did not state. Mr. Willet, however, still held to his opinion that, as a general rule, the plans hitherto tried along the north-east coast of Scotland for concrete-work, had not been altogether successful; and he could not agree with such a principle as that laid down by Mr. Cunningham, that it was more judicious to risk a little in the construction of such harbour works, than to construct them with such a proportion of cement as would make them secure, although the after-expense of maintenance should be slightly increased. He was strengthened in his opinion by the remarks on the Paper, where it was to be observed that the proportion of about 1 part of cement to 6 parts of gravel, stone and sand, appeared to be generally approved of, for such exposed works as existed on the north-east coast of Scotland.

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23 and 30 November, 1886.

EDWARD WOODS, President,
in the Chair.

The discussion, upon the Papers by Messrs. Kinipple, Kyle, Carey, Strype, Willet, and Langley, on "Concrete as applied in the Construction of Harbours," occupied both these evenings.

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7 December, 1886.

EDWARD WOODS, President, in the Chair.

The following Associate Members have been transferred to the class of

Members.

John Duncan Grant.
William Henry Greenwood, Wh.Sc.
Frederick Griffith.
Henry Graham Harris.
Rudolph Hering.
Edmund Gerald James McCudden.
Henry William Pearson.
David Alan Stevenson, B.Sc., F.R.S.E.
George Henry Sykes, M.A.
Arthur Thomas Walmisley.

The following Candidates have been admitted as

Students.

Charles Anthony, Jun.
James Glencairn Armour.
George William Percy Atlay.
Edward Pemberton Banister.
Ernest Mortlock Barton.
Frank Edward Beadle.
George Blair.
William Cameron Borrowman, Wh.Sc.
Samuel Watkin Carlton.
Nai Sai Choduck.
Thomas Clarkson, Wh.Sc.
William Bartholomew Cole.
John Pearson Copland.
Francis Dundas Couchman.
John Cowan, Jun.
Harry Augustus Frederick Currie.
Henry Deanesly.
John Donaghue, A.K.C.
William Ben Edwards, B.E.
Thomas Wharton Ford.
James Grierson, Jun.
Bernard Heaton.
Sydney Thomas Edward Heaton-Ellis.
Edward Thomas Hildred.
William Henn Hinde.
John Holliday.
Percy Philip Hore.
Ernest Worthy Horne.
William Augustus Hough.
Henry Bentley Jameson.
Robert Johnston, Wh.Sc.
James Howie Kirkwood.
Arthur James Knowles, B.A.
Sydney Le Gros.
Alfred James Linnell.
Percy Archibald Low.
George Trotter Lynam.
Augustus Henry MacCarthy.
Frederick James Matheson.
Charles William Mathews.
Ernest Oscar Mawson.
Matthew Mawson.
George Pilkington Mills.
Arthur Ford Pilcher Moore.
Kentish Moore.
Thomas Reade Moore.
Edward Llewewg Morgan.
Matthew James Morrison, B.Sc.
George Aveling Nairn.
Frank Edward Nathan.

Students—continued.

PERCY NEVILL.
EDWARD JAMES PALMER.
RICHARD PARRY.
JOHN WILLIAM PILDITCH.
CHARLES PERCY RAMMAGE.
LESLIE HUNTER REYNOLDS.
GRIFFITH ROBERTS.
FREDERICK SANDERSON ROBINS.
WALTER ROOPE.
FREDERIC CAMPBELL ROSE.
HENRY THORNTON RUTTER.
EDWARD FRANK SARGEANT.
EDGAR SPENCER SAUNDERS.
WALTER NITHSDALE SCOVELL.
HARRY STOREY.
EDWARD HENRY TABOR.
THOMAS KENNARD THOMSON.
WILLIAM TOWER.
CHARLES BRANDON TRYE.
ALFRED HUGH TYLER.
EDWARD OSBORN WARNE.
FREDERICK HOWARD WATSON, B.A.
CHARLES THEODORE HERMANN WEISS.
RICHARD WALSINGHAM WESTERN.
MARTIN STANLEY WHEATLEY.
RICHARD GEORGE HANSFORD WORTH.
GERALD MERRETT WYNTER.
GENJIRO YAMASAKI.

The following Candidates were balloted for and duly elected as

Members.

WILLIAM DUFFY.
WILLIAM GALWEY, M.E.
WILLIAM HENRY GREENE.
JOHN MUIR HETHERINGTON.
PEYTON JONES.
ERASMUS DARWIN LEAVITT, Jun.
BOWMAN MALCOLM.
CHARLES EDWARD PERRY.
JAMES STIRLING.
FRANCIS BLENNERHASSETT WALKER.
WALTER STUART WILSON.
GEORGE KIFT WINTER.
ROBERT EDWIN WRIGHT.

Associate Members.

WILLIAM HENRY ANGOVE.
ALFRED ATKINS.
MOHENDRO NATH BAGCHI.
THOMAS BLAMEY BARRATT.
SYDNEY RUSSELL BARRETT.
ALFRED CHAMPNEY BOTHAMS, Stud. Inst. C.E.
JOHN SHANKS BRODIE.
ROBERT BRODIE, Stud. Inst. C.E.
JAMES BURNETT.
THOMAS WILSON CAIRNCROSS.
THOMAS CALLEN.
ALBERT BARNES CHAPMAN.
HARRY WITHERS CHUBB.
CHARLES BROOKS CLARK.
WALTER JOSEPH COLES, Stud. Inst. C.E.
MONTGOMERY PENROSE COODE.
HENRY HERBERT CRABTREE, Stud. Inst. C.E.
HENRY ALBERT CUTLER, Stud. Inst. C.E.
MAURICE DEACON.
ALBERT DENISON.
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RALPH THOMAS DENNE.
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(*Paper No. 2179.*)

"The Electric Lighthouses of Macquarie and of Tino."

By JOHN HOPKINSON, M.A., D.Sc., F.R.S., M. Inst. C.E.

THE subject of the use of electric light in lighthouses was fully discussed at the Institution in 1879, when Papers by Sir James Douglass, M. Inst. C.E., and by Mr. James T. Chance, Assoc. Inst. C.E., were read.[1]

The subject has been further elaborately examined by Mr. E. Allard,[2] and more recently in practical experiments, made at the South Foreland, exhaustively reported on by a Committee of the

[1] Minutes of Proceedings Inst. C.E. vol. lvii. pp. 77 and 168.
[2] Mémoire sur les Phares Électriques, 1881.

Trinity House.[1] The justification of the present communication is that, at the lighthouses of Macquarie and of Tino, the optical apparatus is on a larger scale than has hitherto been used for the electric arc in lighthouses, and presents certain novel features in the details of construction. Further, as regards the electrical apparatus, tests were made upon the machinery for Macquarie when it was in the hands of Messrs. Chance Brothers and Company, which still possess some value, although five years old; and, in the case of Tino, the machines are practically worked together in a manner not previously used otherwise than by way of experiment.

In the case of both lighthouses, Messrs. Chance Brothers and Company, of Birmingham, entered into a contract for the supply of all the apparatus required, including engines, machines, conductors, lamps, optical apparatus, and lanterns; and Sir James Douglass, Engineer-in-Chief of the Trinity House, acted as Inspecting Engineer to the respective Colonial and Foreign Governments.

As these two lighthouses present many features in common, it may be most convenient to give a full description of the earlier lighthouse, and then limit the description of Tino to those points in which it differs from Macquarie.

MACQUARIE.

This lighthouse is situated on South Head, near Sydney, the precise position being shown in a copy from the chart, Plate 9, Fig. 1. A lighthouse was first placed at this important landfall in 1817. The focal plane is 346 feet above the sea, and the distance of the sea-horizon is therefore 21·6 nautical miles, and the range about 27 nautical miles for an observer 15 feet above the sea.

Optical Apparatus.—The light is a revolving one, giving a single flash of eight seconds duration every minute. On account of the considerable altitude of the lighthouse, it was necessary to secure that a substantial quantity of light should be directed to the nearer sea; but it was also essential, on account of the exceptional power of the apparatus, that this dipping light should only be a small fraction of that sent to the horizon, otherwise its effect would be excessively dazzling. Many years ago, Mr. James T. Chance urged that it was not wise to make use of very small apparatus for the electric arc, because a larger apparatus renders it possible for the optical engineer to effect with greater precision the distribution of light which is most desirable, and

[1] Report into the relative merits of Electricity, Gas, and Oil as Lighthouse Illuminants. Parts 1 and 2. PP. 1885.

because any trifling error which may occur in the position of the electric arc has, with the larger apparatus, a less marked effect on the light as seen from the sea. In the lighthouses of Souter Point, the South Foreland, and the Lizard, the third-order apparatus of 500-millimetre focal length was adopted. Optically, the larger the apparatus used the better, but there might be some question whether, on purely optical grounds, the advantage of going beyond the third order is sufficient to justify the additional expense, but in the case of a revolving apparatus, the third order is a very inconvenient size for the service of the lamp; it is too large to be conveniently served from the outside, and too small to admit the attendant within it with comfort. With the large currents, which are now easily obtained and are likely to be used in lighthouses, a first or second order apparatus has the further advantage that it is less liable to injury from particles thrown off from the heated carbons. In the case of Macquarie, it was decided to adopt an apparatus of the first order, 920-millimetre focal length; it was further decided that the optical apparatus should produce its condensing effect by means of a single agent; that is to say, the vertical straight prisms which were used in Souter Point and other revolving electric lighthouses should be dispensed with. The condensation and distribution of light necessary may be obtained by means of a single agent, with apparatus such as has been proposed by Mr. Alan Brebner, jun., Assoc. M. Inst. C.E.;[1] but this construction is open to the objections that it is somewhat costly, and that it increases the length of the path of the rays through the glass, and consequent absorption. A practically better plan is to adopt forms not differing very greatly from those introduced by Fresnel; to specially arrange them for the purpose in hand, and to accept certain consequent minute deviations from a mathematically accurate solution for the sake of advantages of greater importance, when all the actual conditions are taken into account. Plate 9, Fig. 2, shows the optical apparatus in vertical section; the upper and the lower totally-reflecting prisms are, as is usual in revolving lights, forms of revolutions about a horizontal axis; they direct the light incident upon them to the horizon and the distant sea from 10′ above the horizon to 30′ below; they are specially adjusted to distribute the light in azimuth over the arc of 3° necessary for a proper duration of flash.

The refracting portion of the apparatus has the profile so calculated that the central lens, and the three rings next to the

[1] Minutes of Proceedings Inst. C.E. vol. lxx. p. 386.

lens above and below, direct their light to the horizon without vertical divergence, except what is due to the size of the arc; the light for the nearer sea is obtained from the remaining ten lens-segments, Nos. 5 to 9 inclusive, above and below the centre, counting the centre as No. 1, the distribution being according to the following Table, in which the first column gives the denomination of the elements of the lens in accordance

I.	II.			III.		
	°	′	″	°	′	″
9 top		−10	0	2	30	59
8 "	2	30	59	5	8	52
7 "		−10	0	2	37	30
6 "		−10	0	1	30	0
5 "		−10	0	1	0	0
5 bottom		−10	0	1	0	0
6 "		−10	0	1	30	0
7 "	1	30	0	3	44	27
8 "	3	44	27	5	50	41
9 "	5	50	41	7	46	57

with the numbers marked upon the section; the second, the angle between the direction of the sea-horizon and the ray emerging from the upper limit of the element; the third, the angle between the direction of the sea-horizon and the ray from the lower limit of the element, the negative sign denoting that the emerging ray is above the horizon. This practice, of appropriating certain elements of the apparatus to different distances on the sea, was first introduced by Mr. James T. Chance, in the lights of the South Foreland exhibited in January 1872.

The ray, dipping at an angle of 7° 46′ 57″ below the horizon, will strike the sea at ½ mile, while 5° 8′ 52″ corresponds to ¾ mile, 2° 37′ 30″ to 1¼ mile, 1° 30′ to 2 miles, 1° to 2½ miles, and 30′ to about 4 miles. Thus the direct light begins at about ½ mile from the lighthouse. From ½ mile to ¾ mile the sea receives light from one element of the apparatus, from ¾ to 1¼ mile from two elements, from 1¼ mile to 2 miles from three elements, from 2 to 2½ miles from four elements, and beyond 2½ miles from six elements; the upper and lower totally reflecting prisms come in aid at about 5 miles. The main power of the apparatus is hardly attained till a distance of 8 or 10 miles. Fig. 3 is a sectional plan of the apparatus by a horizontal plane through the focus. It will be seen that a dioptric mirror is placed on the landward side of the arc. This mirror is arranged to form the image of the arc at one side of the carbons, so avoiding the interception of light

which would result if the mirror were used in the ordinary way, and contributing to the horizontal divergence necessary. Further horizontal divergence is given by the form of the lens. In the ordinary revolving light the inner face of the lens is plane; here it is cylindrical, the axis of the cylinder being vertical. This method of obtaining horizontal divergence is a modification of a proposal of Mr. Thomas Stevenson,[1] M. Inst. C.E.; it is not mathematically accurate, inasmuch as the cylindrical form of the inner face of the lens not only displaces the emergent ray horizontally, but also in the case of rays not in the vertical nor horizontal plane through the focus, to a small extent vertically, but the error is easily calculable, and is unimportant, provided the lens is narrow, and the horizontal divergence of the beam moderate. Plate 9, Fig. 4, shows a complete panel in elevation with revolving carriage. Fig. 5 shows the plan of the service-table of the pedestal and lamp-table. A new construction was adopted for the gun-metal framework of the optical apparatus to reduce the interception of light by the frame to a minimum. The metal segment A, Fig. 6, forms part of the lower prism-frame, B part of the upper frame, whilst C and D are parts of the frame for the refracting portion of the apparatus; uprights E support the upper prism-frames without throwing weight on the lens-frames. With the ordinary constructions of frame, Figs. 7 and 8, the equivalent of these ring segments A and B would intercept about double as much light as in this new construction.

Mechanism for Rotation.—The pedestal is similar to those designed by Sir James Douglass to permit the light-keeper to obtain access from below to the interior of the apparatus without in any way interfering with its rotation. The clock-work is fitted with the governor, and maintaining power used by Messrs. Chance Brothers and Company for the last twelve years. The roller-ring may be mentioned as of an improved type, for although it has been used for some years in all Messrs. Chance's lights, it has not been described before. The rollers and roller-paths which carry the whole weight of the optical apparatus have long been made conical, so that the surfaces roll upon each other without twisting. There is consequently a very considerable radial force on each roller tending to force it outwards, the reaction against this force causes a very important part of the total frictional resistance. Plate 9, Fig. 9, shows a portion of the roller-ring and one of the conical rollers, according to the old construction, Figs. 10, 11, according

[1] "Lighthouse Construction and Illumination," p. 186.

to the improved construction; in the former it will be observed that the thrust of the roller is received on a collar; in the latter, on the end of a pin. The reduction of friction is practically very considerable, and although of small importance in a slow-moving apparatus like Macquarie, is of great importance in heavier and quicker apparatus; for example, the triple-flashing light at Bull Point, in Devonshire.

Lamps.—These are of the Serrin type, and were supplied by Baron De Meritens.

Lamp-Table.—The arrangements for rapidly changing electric lamps, and for substituting gas or oil when desired, are shown in Figs. 12, 13, 14, 15.

The intention was to use a gas-lamp in clear weather, and half-power or full-power electric light in thick weather, according to the opacity of the atmosphere; but the Author understands that in practice the electric arc is always used. The paraffin oil-lamp is intended as a resource in case of failure of the supply of gas.

Focussing the Arc.—Two approximately rectangular prisms are fixed upon the mirror frame at about 90° from each other, the longer face of each is plane, the other two faces convex, of such curvature as to form a good image of the arc upon the service-table, as shown in Fig. 16. During daylight, a pointed sight or focimeter is placed at the position of the image formed by the lens of an object on the horizon; this then is the position which the arc should occupy. A sight is next taken over the focimeter into one of the adjusting prisms, and a bright object such as a threepenny piece placed on the service-table, is moved about until its centre is seen in the prism, exactly upon the point of the focimeter; a mark is made in the then position of the object. When the arc is correctly adjusted, its image on the service-table will be at the point where the mark is made. Two prisms are used in order to secure that the arc shall be in the centre of the apparatus as well as at the correct level.

Lantern.—The lantern is of the well known Douglass type.[1]

Dynamo-electric Machines.—Two alternate-current machines, with permanent magnets manufactured by De Meritens, were supplied. Each machine has five rings in its armature, and in each ring there are sixteen segments. In supplying one arc for a lighthouse the machine runs about 830 revolutions per minute, and gives a current of 55 amperes when half the coils are used, and of 110 when the whole of the machine is in action, the internal resistance

[1] Minutes of Proceedings Inst. C.E. vol. lvi. p. 77.

in the two cases being 0·062 and 0·031 ohm. It is unnecessary to give a description of the machine as its general construction and dimensions are well known, but some numerical details are given below.

Engines.—Each machine is driven by an 8 HP. Crossley gas-engine through a belt without countershafting.

Tests.—Whilst the dynamo machines were at the works of Messrs. Chance Brothers and Company, a series of experiments was made in March 1881 to determine their properties. The time is long passed when it would be profitable to give the details of these experiments, but the general conclusions drawn at the time are still interesting. When the external resistance was a metallic conductor with small self-induction, it was found that with varying resistance and speed the currents observed agreed fairly well with calculation from the formula $\frac{A}{\sqrt{R^2 + \left(\frac{2\pi\gamma}{T}\right)^2}}$,[1] in which R is the total resistance of the circuit, γ the self-induction, and T the periodic time. When the machine was running 830 revolutions per minute A = 67 volts and $\left(\frac{2\pi\gamma}{T}\right)^2 = 0\cdot197$ in ohm squared, hence $\gamma = 6\cdot4 \times 10^5$ centimetres. The eighty sections of the machine are arranged four in series, twenty parallel. For a single section the value of γ would be 32×10^5 centimetres. The maximum induction in the core, which has an area of 5 square centimetres, is 24,600 or 4,920 per square centimetre. The loss of power was greater when the machine was doing little or no external work than when that work was great. This is clearly seen in the following Table :—

Current amperes	7·70	73·60
Electrical work HP.	0·69	5·66
Mechanical work applied . . .	3·09	6·55
Loss	2·40	0·89

Photometric experiments were made upon the arc, and simultaneous measurements of effective power applied and of current passing. The red light was measured through bright copper ruby glass, and the blue through a solution of sulphate of copper and ammonia. The HP. was measured by a transmission dynamometer; but the results must be accepted with some reserve, on account of the difficulty of ascertaining the mean tension in a strap which

[1] Lectures on the "Practical Application of Electricity." Session 1882-83. "Some points in Electric Lighting." By Dr. John Hopkinson. p. 88.

is constantly varying. The oscillations of the dynamometer were damped by a dashpot containing tar.

	Half Power.	Full Power.
Red candles	1,988	4,708
Blue „	4,079	11,382
Current (amperes)	54·5	105
Mechanical power applied (HP.)	4·5	6·9
Power expended in heating conducting wires (HP.)	0·24	0·95

The results illustrate the fact that, as the current increases, the total light increases in a higher ratio, red light in a slightly higher ratio, and blue in a considerably higher.

The machinery for this lighthouse was sent out to New South Wales in November 1881, and was put up and started under the superintendence of Mr. J. Barnett, the Architect of the Colony, to whom is mainly due the success of the whole from the first start. The glare of the light upon the sky is said to have been seen at a distance of over 60 miles, far beyond the distance at which it would cease to be directly visible. The only criticism from mariners has been that when somewhat near the lighthouse the flashes are so bright as to dazzle the eye. This is an excellent proof of the power of the light, as a much smaller proportion of the light is directed upon the nearer sea than in any previous lighthouse. The lesson is that with powerful electric lighthouses almost all the light should, in ordinary weather at least, be directed to the horizon, and that the quantity thrown upon the nearer sea must be strictly limited. This is only possible when the focal length of the apparatus is large.

Tino.

This station is on a small island at the mouth of the Gulf of Spezia. Fig. 17, Plate 9, is copied from the chart of the neighbourhood. The focus is 386 feet above sea-level. The distance of the sea-horizon is 22·7 nautical miles, and the range practically 28 miles. The conditions, therefore, were very similar to those of Macquarie, with the exception that it was required to throw some light down into the channel between Palmaria and Tino. The lighthouse itself presents some interesting historical features. The buildings were originally a place of defence against the pirates who occasionally made descents upon the coast. Subsequently a coal-fire lighthouse was established, and in the spring of 1885 part of the stock of lignite was still found to be in some of the buildings, where it had been lying for fifty years. In 1839 a dioptric light was established, one of the earliest of

Fresnel's types, the lens-ring being replaced by short straight prisms, which formed by no means a bad approximation, and could be ground without special machinery. The present electric lighthouse has been in contemplation for several years.

Optical apparatus.—The distinctive character of the light is a triple flash every half minute. The apparatus for producing this effect is of the general form introduced by the Author in 1874. In October of that year he issued a pamphlet pointing out the several advantages of group-flashing lights, showing for the first time a simple dioptric apparatus suitable to their production, and also pointing out how easy it is to give the group-flashing effect with catoptric apparatus. Since that time a large number of dioptric group-flashing lights have been made by Messrs. Chance Brothers and Company, and some also in France, and Mr. Allard has incorporated group-flashing lights in the system of distinctions he recommends; also a considerable proportion of the light-vessels on the English coasts have been converted into group-flashing lights of the catoptric system. On the ground of economy the second-order apparatus of 700-millimetre focus was adopted in the case of Tino. It is just large enough for tolerably convenient service of the lamp by an attendant entering within the apparatus. The apparatus, shown in vertical section in Fig. 18, and in horizontal section through the focus in Fig. 19, has twenty-four sides, eight groups of three; one group of three is shown in elevation in Fig. 20. The horizontal divergence is obtained in exactly the same way as at Macquarie, excepting that no mirror is used. The metal framework, however, approximates to the ordinary type, as the type used at Macquarie would have been costly when applied to a triple-flash light. The distribution of light vertically is as follows: upper and lower prisms, and the central lens, with the two lens-rings next adjoining it, all to the horizon and most distant sea. The lens and lens-rings direct their rays according to the following Table, which is arranged in exactly the same way as the Table already given for Macquarie—

I.	II.	III.
	° ′ ″	° ′ ″
7 top	0 31 35	3 16 0
6 "	..	2 0 0
5 "	..	1 30 0
4 "	..	1 0 0
4 bottom	..	0 45 0
5 "	..	0 30 0
6 "	..	0 30 0
7 "	all to the horizon.	

No. 7 bottom was directed wholly to the horizon, in order to avoid the horizontal bar of the lantern. It will be observed that the quantity of light thrown upon the nearer sea is much less in the case of Tino than in that of Macquarie, and that greater reliance is placed upon the accuracy with which the arc can be kept in focus; experience has justified these changes, as improvements of a perfectly safe nature.

A small part of each flash is bent downwards and distributed over the channel between Tino and Palmaria, by means of subsidiary prisms fixed upon the lantern, shown at X, Fig. 18. These subsidiary prisms are really superfluous, as the scattered light from the beams overhead is found to be as effective at this short distance. Fig. 21 shows the plan of lamp shunting-table and service-table.

Engines.—As there is no water upon the island, the practice of the Trinity House was followed, and two of the Brown hot-air engines were supplied, each driving through a countershaft one of the machines. The countershafts could be connected by means of a Mather and Platt friction-coupling, so that the two machines could be driven together, or either machine from either engine. Drawings of the Brown engines are given in Sir James Douglass's Paper.[1] The accompanying indicator-diagrams were taken from the compressing- and working-cylinders. Whilst these diagrams were taken, the effective power developed was measured by a friction-brake on the driving-pulley, and was found to be 9·1 HP. Thus of 33·1 HP. indicated in the working-cylinder, 17·7 HP. is employed in compressing the air, 6·3 HP. is wasted in friction in various parts of the machine, and only 9·1 HP. is effective upon the brake. The engines consume about 4 lbs. of coke per effective HP. per hour. In future lighthouses, when a steam-engine cannot be employed, it would be preferable on every ground to use gas-engines, and manufacture on the spot either Dowson gas or ordinary gas, according to the character of the fuel available.

Dynamo Machines.—There are two machines of exactly the same type as those supplied for Macquarie, the only novelty lying in the method of using them. In 1868 Mr. Wilde discovered, by experiment, that two alternate-current dynamos, independently driven at the same speed, would, if electrically connected, so control each other's motions that they would add their currents. The Author subsequently arrived at the same conclusion independently, on theoretical grounds, and gave a thorough explanation of the

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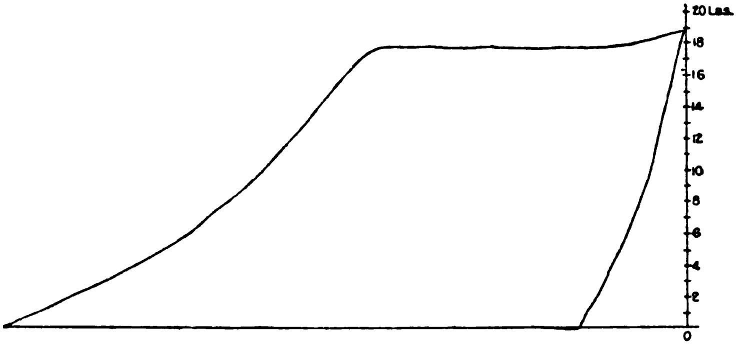
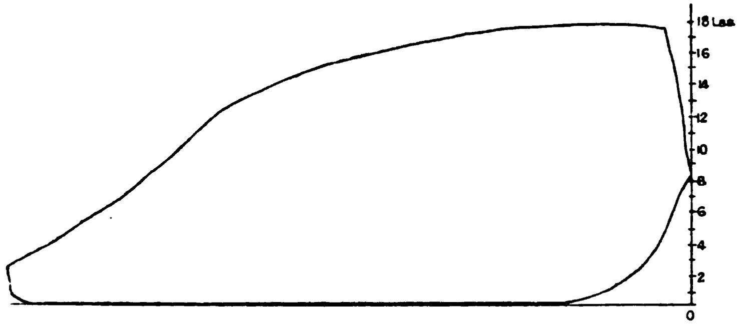
[1] Minutes of Proceedings Inst. C.E. vol. lvii. Plate 6.

fact.[1] The result has been put to a practical application at Tino. The machines are connected to a single switchboard, so that each half of the two machines can at pleasure be connected to, or disconnected from, the main conductors. Thus a current can be supplied from either machine at half power, 55 amperes, or full power, 110 amperes, or from the two machines of double power, or about 200 amperes. Further, a change can be made without



Compressor pump-cylinder, 24 inches in diameter. Stroke, 22 inches. Indicated HP., 17·7.



Working-cylinder, 32 inches in diameter. Stroke, 20 inches. Indicated HP., 33·1. Revolutions per minute, 64. Power on brake on fly-wheel, 9·12 HP. Pressure in reservoir, 19 to 24 lbs.

extinction of the light from one dynamo and engine to the other. Thus, suppose one machine is working full power, clutch the countershafts gradually together, so starting the second engine; throw on the band of the second machine, cut out half the first machine, and connect half the second machine at the switchboard;

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[1] Lectures on the "Practical Applications of Electricity." Session 1882–83. "Some Points in Electric Lighting." By Dr. John Hopkinson. And Journal of Society of Telegraph-Engineers and Electricians, vol. xiii. p. 496.

the two machines at once synchronize, without affecting the light. Disconnect the remaining half of the first machine, and connect the remaining half of the second, unclutch the countershafts, and stop the first engine. One man can effect the change, with no more disturbance of the light than a change from full to half power for about one second. A further conclusion, deduced from theoretical considerations, was that of two alternate-current machines of equal potential, one could be used as a generator of electricity, the other as a motor converting the current generated back into mechanical power. It was found impossible to verify this conclusion with such intermittent driving as that of a hot-air engine. But Professor W. G. Adams effected the verification without difficulty at the South Foreland, the motive-power being steam.

Lamps.—These are the improved Serrin of Mr. Berjot. One of the three lamps supplied is of larger size, for the double-power current from the two machines. This lamp was said to be suitable for a still greater current, but with about 200 amperes it soon became dangerously heated; a simple modification rendered the lamp equal to the actual work it had to do. It is, however, probable that for the occasional circumstances when it is necessary to use so great a current as 200 amperes in a lighthouse, a lamp worked partly by hand would be preferable to a regulator entirely automatic.

The apparatus was delivered in November 1884, and was put up by workmen from Messrs. Chance's workshops, under the supervision of Mr. L. Luiggi, of Genoa, to whose ability and energy the complete success of the lighthouse is largely due. A complete test of the performance of the light, as seen from the sea in all grades of its power, was made in April 1885 by a Commission, consisting of Professor Garibaldi, of Genoa; Mr. Giaccone, Engineer-in-Chief for Italian Lighthouses; Captain Sartoris, and Mr. Luiggi, the Author attending on behalf of Messrs. Chance. The light was well observed through rain, when distant 32 nautical miles, and although below the horizon, the position was precisely localized, and the triple-flash distinction unmistakable. At 18 miles distant the illumination of the flash upon white paper was sufficient to make out letters marked in pencil 1½ inch high, and when 14 miles distant it was easy to ascertain the time from a watch. The light is frequently seen at a distance of 50 miles, near to Genoa.

A review of work which has been carried out naturally suggests many questions as to what conclusions experience has established,

and what indications it gives of the probable direction for future developments. In the use of electric light in lighthouses, there are many questions upon which there is wide difference of opinion, questions both as to when and where electric light should be adopted, and questions as to the best way of employing it. It may not be unprofitable to allude to some of them. Although English engineers are now well agreed that a large optical apparatus should be used for electric light, this opinion is not universally accepted. The advantages of a large apparatus have already been mentioned. To balance them, there is nothing on the other side but the less prime cost of the smaller apparatus. Although the difference of cost appears considerable when attention is confined to the optical apparatus, it is unimportant when the whole outlay on the lighthouse is brought into account. Cases are, however, conceivable in which a small optical apparatus such as a fourth-order, having a focal distance of 250 millimetres, would be properly preferred; such, for example, as a harbour light which could be supplied with current from machinery also used for other purposes, but such cases are likely to be exceptional.

When a flame from oil or gas is the source of light, there is of necessity a considerable divergence vertically; and the distribution of the light through the angle of vertical divergence is not at disposal, except to a very limited extent in some cases, but is determined by the size and character of the flame. With the electric arc and a large optical apparatus it can be determined in considerable measure how the light shall be distributed—how much shall be sent to the distant sea, how much to the various distances between the foot of the tower and a distance of some miles. It becomes then a question what use is to be made of this facility. The experience at Macquarie and at Tino is emphatic, that it is in every way advantageous to direct much the greater part of the light to the horizon with a very small divergence, and to distribute the comparatively small remainder over the nearer sea with intensity increasing with the distance.

A question allied to the last is this: Whether it be desirable to provide means of directing the strongest light downwards on to the nearer sea in time of fog? The answer must depend upon the circumstances of the particular locality. Take the case of a lighthouse on an isolated rock, the purpose of which is primarily to be a beacon to keep ships off that rock; a lighthouse which would not exist were it not more practical or cheaper to build and maintain the lighthouse rather than remove the rock. Here surely it is of the greatest use to provide means whereby, if the light cannot

penetrate 2 miles, it shall if possible be visible at 1 mile. But other cases occur in which the lighthouse has to cover a long length of coast, and has almost as much to do with points of the coast 10 miles distant as with the point upon which it is placed, cases in which the lighthouse is far more useful in guiding the regular traffic passing within a radius of 20 miles or more than in preventing vessels running ashore within a mile of the tower. Such a light fails of its purpose if it can only be seen at a distance of a mile, covering less than $\frac{1}{400}$ part of its normal area of illumination; it becomes comparatively useless unless it penetrates to something like its normal range, and its efficiency must be measured by the fewness of the occasions when it fails to do this. It is a grave question whether it be prudent in such cases to place upon the light-keeper the responsibility of judging when the light should be dipped on to the nearer sea, the fact being that, if his judgment errs, he may actually diminish the range of the light, and cause unnecessarily the lighthouse to fail of fulfilling its most important function. It is easy for him to be misled if the fog is local and does not extend to any great distance from the lighthouse. Another element enters into the consideration—the height above the sea. If the focus be 100 feet above the sea-level, the dip of the sea-horizon is 9′ 45″, and a ray dipping 9′ 45″ below the sea-horizon will meet the sea at a distance of 3·1 nautical miles from the tower. Even with a first-order apparatus, if the arc be a powerful one, it is very difficult to render the light directed to the horizon from an elevation of 100 feet more powerful than that directed to a point distant 4 miles from the tower. Unavoidable divergence will render the two intensities practically equal.

Passing to questions of another class, what are the relative advantages in an electric lighthouse of continuous and alternating currents? Present practice tends altogether in favour of alternate currents, but this practice largely results from unfavourable experience of the older continuous-current machines. These machines have in many respects been greatly improved in the last two or three years. The continuous current presents the advantage of greater economy of power in producing the current, less floor-space required by the machine, and a smaller prime cost. The alternate-current magneto machine, on the other hand, has the advantage that it may be driven with a defectively governed prime mover, with an indifferent lamp, and may suffer neglect with impunity; whereas the more compact and efficient continuous-current machine would be in serious peril of destruction. Optical apparatus can

be constructed suitable to make the most of either form of arc. Hot-air engines have found favour for electric lighthouses, because in many cases there is no available supply of fresh water. The engines of which the Author has experience are open to the objection that they take a great deal of room, are not economical of fuel, and do not govern so quickly as is desirable; the wear and tear also, when they are worked to anything like their full power, is very serious. A gas-engine, with Dowson or other gas made on the spot, could be used with greater advantage.

Antecedent to all considerations as to the best apparatus and machinery to be used, is the question, under what circumstances, if at all, should electric light be used in a lighthouse? The Trinity House experiments at the South Foreland showed to demonstration that, where the issue to be decided was how to produce a light which should be capable of penetrating the furthest in all weathers, electric light could do that which could be done in no other way, and that it was the cheapest light of all when the price is estimated per unit of light. But the conclusion was also reached that an electric light must inevitably cost a large sum, both in first outlay and in maintenance; therefore that electric light is extravagant unless very extraordinary power is a necessity. This conclusion is doubtless a fair consequence of experience, but it is not an inherent property of electric light. Both the capital outlay and the cost of maintenance are greatly increased by the practice of so arranging the machinery as to provide, at all times, a light of very great power: whence follows that the machinery must be placed at some distance from the lantern, and two men must always be on duty; one man in the lantern, and another with the machinery.

The essentials for a cheap electric lighthouse are, that for ordinary states of the atmosphere there shall be provided a plant under the easy control of the light-keeper himself, which shall be precisely adapted to produce that amount of light which is wanted in ordinary states of the atmosphere; but for thick weather there shall be provided a much more powerful engine and dynamo, available also as a reserve in case the smaller machinery from any cause breaks down. The occasional machinery may be more remote from the lantern, as it is a small matter to require a second man to work on the comparatively rare occasions when the maximum power is needed. A small gas-engine and a dynamo machine can be placed without any crowding in the room immediately below the lantern, and arrangements can be made whereby the light-keeper, whether he is in the lantern or in the engine-room, can ascertain at a glance

whether the arc is in its proper position, with an error of less than 1 millimetre. The attendance on the lamp, rotating apparatus of the lens (if a revolving light), engine and dynamo, would be easy when the whole is brought together, so as to be under observation at once; in fact the gas-engine, dynamo, and lamp constitute together a gas-burner which, though consisting of many parts, is automatic throughout, and requires nothing but the constant presence of a custodian, exactly as the gas-lamp in a lighthouse requires a custodian, as a guarantee against failure. The same end, viz., the concentration of the whole mechanical and electrical apparatus under one pair of eyes, could be attained, of course, in other ways. Accumulators could be used, or a petroleum-engine.

In order to give definiteness and afford facilities for criticism, the better course will be to describe a suitable machinery; state what it will do, what attendance it will require, and what it will cost. The Author proposes, then, for an electric lighthouse where small outlay is essential, the following:—A Dowson gas-producing apparatus and gas-holder, the generator and superheater being in duplicate, each capable of making 1,200 feet of gas per hour, the gas-holder having a capacity of 3,000 cubic feet.

An 8-HP. nominal Otto gas-engine and series-wound dynamo-machine, placed in a room near the base of the tower, and copper conductors to the lantern, the dynamo having magnet coils, divided into sections so as to supply a small current when required.

A 1-HP. nominal Otto gas-engine and dynamo machine, placed in the room immediately beneath the lantern floor, with gas-pipe from the gas-holder; three electric lamps, to receive either carbons 25 millimetres in diameter or any lesser size, with complete adjustments for accurate focussing; one paraffin lamp as a substitute; an optical apparatus of the second order of 70-centimetre focal distance. The cost of this apparatus would depend upon the character of the light it was intended to exhibit. To fix ideas, let it be assumed that the light is to be a half-minute revolving light, showing all round the lighthouse. There could then be supplied a sixteen-sided apparatus with pedestal and revolving machinery. Provision would be made in the optical apparatus for giving the horizontal and vertical divergence desired by the same methods successfully used in the lighthouses of Macquarie and of Tino.

Two focussing prisms would be fixed to form magnified images of the arc, on pieces of obscured glass let into the pedestal floor, so that the keeper, whether in the lantern or in the engine-room, could see at a glance the state of the arc, and observe whether it

is of proper length with the carbons in line, whether it is exactly at the right height and in the centre of the apparatus. An error of 1 millimetre would be glaringly apparent, and call for immediate adjustment, although its effect would be only a displacement of the beam 5′ of angle.

The lantern would be 10 feet diameter, with bent plate-glass.

The cost of the whole above described would be materially less than the cost of a first-order light and lantern with oil-lamp and large burners.

Now what result would be obtained? In fine weather the small engine would be used. Its effective power on the brake is fully 1½ HP.; from this 1½ HP. the dynamo machine produces considerably over 800 watts, say 800 watts in the arc itself, or 20 amperes through a fairly long arc of 40 volts. Of course the value of this in candles depends upon the colour in which it is measured, and the direction in relation to the axis of the carbons. In red light the mean over the sphere would certainly exceed 1,200 candles. In clear weather or in slight haze or rain, the beam of this light through the lenses would be much more powerful at the horizon and on the more distant sea than any single-focus light with oil or gas as the illuminant, and would at least he fairly comparable with anything yet exhibited with oil or gas whether triform or quadriform. But on the nearer sea the illumination would be reduced, so that no annoyance would be caused by dazzling flashes. In thick weather or indeed in any weather when there was a doubt as to the visibility at the horizon of the lower power, the large engine would be used under the superintendence of the second keeper. This engine will give 10 HP. on the brake, and there is no difficulty in obtaining 85 per cent. of this as useful electrical energy outside the machine, that is, 6,340 watts. From this deduct 10 per cent. for the leads and the lamp and for steadying the arc, leaving 5,710 watts in the arc itself, or 114 amperes, with a difference of potential of 50 volts. Having regard to the fact that the optical apparatus here proposed acts upon a larger portion of the sphere than that used in the South Foreland experiments, that the vertical divergence is less, and that the potential difference is greater and the current continuous, although less in quantity, it may safely be assumed that the power of the resulting beam would not be inferior. It hence follows, from the South Foreland experiments, that in any fog the flashes would penetrate farther than those of any existing gas or oil light. The increased size of crater, compared with that produced by the current of 20 amperes, will give increased vertical divergence, and so cause the maximum illumination to be attained at a less distance

from the lighthouse. The attendance of two men would suffice for all the duties of the lighthouse, because under ordinary circumstances one man only need be on duty excepting for two to three hours whilst gas is being made. The consumption of coal would be 4 lbs. per hour of lighting, of water about ½ gallon, of carbons about 4 inches. The whole cost of maintaining the light would differ little from that of an ordinary oil light of the first order.

Though it be the fact, that it is possible to exhibit an electric light at moderate cost, it does not follow that it is suitable for all ocean-lights. There is no room in a rock lighthouse tower for a gas-plant, and few would at present be prepared to recommend a petroleum-engine burning oil of a low flashing point. The light-keeper again must understand a gas-producer, a gas-engine, a dynamo, and an arc lamp, instead of only a paraffin lamp and burner, and arrangements must exist for repairing the more extensive machinery. Such considerations will justly weigh against the use of electric light in remote stations and in countries where the labour available is not capable of much training.

It may possibly be said that in this Paper no definite conclusions are reached as to whether electricity or some other agent is the best source of light in lighthouses generally, nor yet, if electricity be adopted, what is the best way of producing the light and optically dealing with it. The answer is that it is impossible on many points to arrive at general conclusions. Each case must be judged according to its special circumstances.

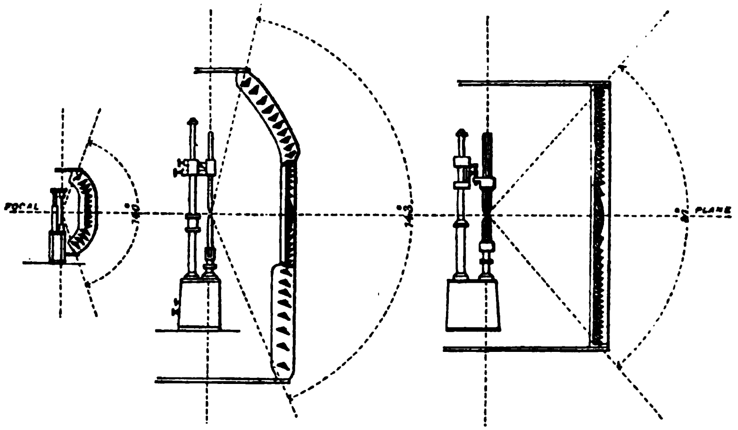
The Paper is accompanied by a lithograph and two tracings, from which Plate 9 and the Figs. in the text have been prepared.

Discussion.

Sir JAMES DOUGLASS said, although as stated by the Author, the subject was discussed in 1879, the present Paper was exceedingly valuable and instructive, in affording another opportunity for considering the important subject of lighthouse illumination generally, and with the aid of the advancement and experience since gained with electric and other methods. As to the works carried out at Macquarie and at Tino, he had had the honour of assisting in them with his advice and inspection, and was therefore able to bear testimony to the careful manner in which the whole had been designed, the excellence of the workmanship, and the success that had attended the undertaking at both stations. The Author had stated that the work suggested "many questions as to what conclusions experience has established, and what indications it gives of the probable direction for future developments." The first conclusion of the Author was the departure from the very small apparatus of 150 millimetres focal distance with ¼-inch by ¼-inch square carbons, first used permanently by the Trinity House, under the advice of Faraday, for electric light. The apparatus and Holmes lamp used at Dungeness from 1862 to 1879 was before the meeting. There was also one of the large De Meritens lamps used in the late South Foreland experiments, fitted with a pair of 50-millimetre cylindrical carbons. It would be impossible to work the arc of these large carbons at the focus of the Dungeness apparatus, seeing that the small ¼-inch carbons were destructive of the surfaces of the lower portions of the apparatus by molten particles thrown upon them. The Author had pointed out that there was obtainable, with a larger apparatus, a better distribution of light, both vertically and horizontally. Moreover, the second order of 700-millimetre focal distance which he proposed, and which was likely to be generally adopted in the future, was just large enough for the admission of a keeper to manipulate the lamps. With regard to cost, the 700-millimetre apparatus compared favourably with those required for the present maximum development of flame lights, being only about one-third. With respect to the optical apparatus used in this country for electric light, Fig. 1 represented that at Dungeness. Fig. 2 represented the apparatus, also composed of a central lens, combined with upper and lower prisms, but of 500-millimetre focal distance, designed for Souter Point and the South Foreland by Mr. James T. Chance, and it nearly represented in form and dimensions the apparatus designed

Sir James Douglass. by the Author for the Lizard. Fig. 3 represented a section of the apparatus, composed of sixteen lenses only, intended for St. Catherine's. Each lens subtended a vertical angle of 97°, and was similar in section to those designed by the Author for Anvil Point and the Eddystone. With reference to the distribution of the light vertically and horizontally, it would appear, considering the dimensions of the present 50-millimetre carbons, that it might be left undisturbed, but that was not so; the focal luminary was much smaller than might be at first realized, and it required optical treatment for perfect distribution between the sea-horizon and the lighthouse, and also for uniformity of intensity through-

Fig. 1. Fig. 2. Fig. 3.



Dioptric Apparatus for Electric Lights.

Scale ¼ inch = 1 foot.

Fig. 1. Dungeness. Focal distance, 150 millimetres.
Fig. 2. Souter Point, Lizard, and South Foreland. Focal distance, 500 millimetres.
Fig. 3. St. Catherine's. Focal distance, 700 millimetres.

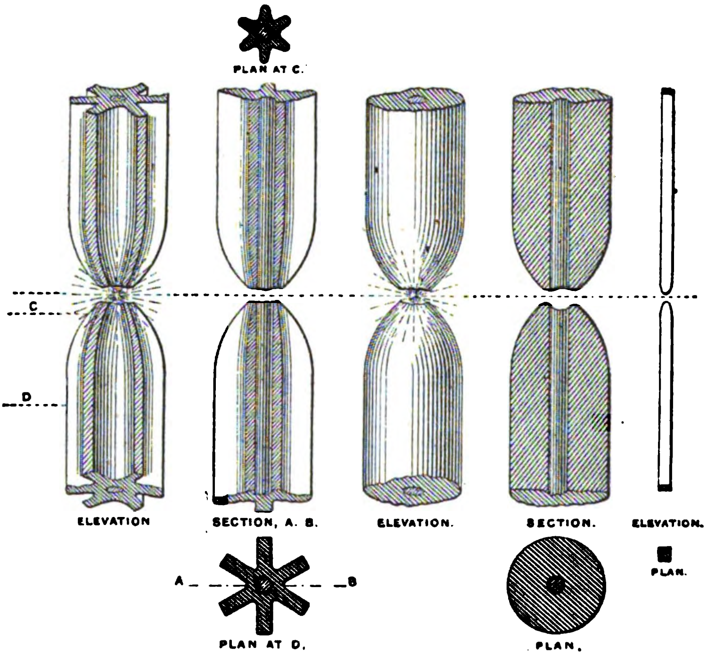
out each flash to be sent from the station. As to the vertical distribution of light, he agreed with the Author that, as hitherto, the maximum light should be adjusted for the horizon, but he did not agree that it should always remain in that state. He thought that the light should be arranged for dipping. In the apparatus intended for St. Catherine's, the dip for, say one-third or one-half range in thick weather, was accomplished by simply raising the carbons and arc over the required angle of dip. The Author had broached the important question of the value of dipping-lights. It was found that, on the coast of this country, impaired atmosphere—he would not say fog—for the transmission of light

Sir James Douglass.

prevailed for about one-third of the year, and therefore it was not safe to venture to protect a coast line positively beyond 4 or 5 miles from a lighthouse. It was well, however, to remember that wherever a lighthouse was established on a commercial track, whether on a rock, sand or headland, mariners availed themselves of it, whenever possible, as an object of guidance by which to verify their position. The chief lights in the English Channel—Scilly, Wolf, Lizard, Eddystone, Start, Portland, St. Catherine's, Owers, Beachy Head, Royal Sovereign, Dungeness, and South Foreland, might be taken as examples. In endeavouring to pick up those lights in succession in thick weather, with careful attention to soundings, which he was sorry to say was often neglected, and when the beam would be going uselessly over the mariner's head, it would surely be better to direct it to a distance, of say 4 or 5 miles, leaving at the same time a fair portion of the light on the horizon. He could never agree to the horizon being deprived of the whole of the light; still he thought the best service to the mariner would be to give him the most intense light at a short range, whenever it could be safely determined that light was not reaching the horizon. Under those circumstances all that was possible would be done, and when the mariner arrived within 2 miles, or perhaps 1 mile, without seeing the light, he should hear the fog-signal and thus be prevented from going ashore. As to the question of when the light should be dipped, that, he thought, was completely met by observations from the station with an observing light at a distance of, say, 10 or 15 miles, and, as was now done, for increasing the coast lights from the minimum to the maximum intensity and *vice versâ*. With reference to the question of alternating currents, in this country and in France the alternating-current machine of Baron De Meritens had latterly been generally adopted from its high efficiency, its durability, and its great reliability, the latter being a most important consideration with everything relating to lighthouse illumination. For the optical focus of a lighthouse apparatus anything more perfect for getting a large vertical angle of light could scarcely be imagined than the arc from an alternating current, where the carbons were well pointed and a crater could be avoided. As to carbons with the direct current for search lights, or a beam required in one direction only, he had nothing to say. Figs. 4, 5, 6 and 7 represented a series of large carbons as used with alternating currents at the South Foreland. In Figs. 6 and 7 the relative dimensions of the crater, which was continually varying in form, might be realized. He had lately made experiments with

Sir James Douglass. a view of preventing the formation of the crater, and in this he had succeeded by carbons of a fluted section, Figs. 4 and 5. With those carbons a steadier light was obtained with a large vertical angle of radiance, and the crater was avoided. Indeed, in the process of burning, the walls of the crater were dissolved. With a solid carbon the crater was continually bursting in one direction or another, thus disturbing the arc; and that, in his opinion, was the chief cause of the disturbances in the intensity of arc lights.

Fig. 4. Fig. 5. Fig. 6. Fig. 7. Fig. 8.



Figs. 4 and 5. Fluted Craterless Carbons, 50 millimetres in diameter.
Figs. 6 and 7. Solid Carbons, 50 millimetres in diameter.
Fig. 8. Original Dungeness Carbons, 6¼ millimetres square.

Large carbons were now manufactured of excellent quality, especially core carbons by Messrs. Siemens, but even with those there was frequent bursting of the crater, and consequent disturbances in the arc. He had had a few fluted carbons moulded, but the experiments were first made with carbons cut from the solid. Yet another point observed in working with large carbons was, that an internal fracture caused disturbance of the arc, and continued to do so until the fracture was completely burnt down. With fluted carbons fractures were less frequent, the carbons being better baked.

So far he had found the higher intensity of the light with fluted carbons not less than 10 per cent. With regard to the important question of a probable reduction in the cost of installation and maintenance of electric lighthouses, the development that had already occurred, should first be realized, and how the matter at present stood as to the relative cost of electric light and flame lights. When electric light was established at Dungeness in 1862, the arc with a pair of carbons 6½ millimetres square (Fig. 8), had a mean intensity, estimated from repeated measurements, of 670 candles; the intensity of the first-order colza lamp did not then exceed 250 candles, a proportion of nearly 3 to 1. The cost of the lights per focal unit per annum, inclusive of interest on outlay for station machinery and apparatus, cost of wear and tear, &c., was for electric light 47*s.* 7*d.*, and for oil 52*s.* 9*d.* At Souter Point, installed in 1870, the intensity of the focal light was increased to 3,000 candles, and the cost of that light per focal unit per annum, calculated as before, was only 12*s.* In the recent South Foreland experiments, it was practically demonstrated that an electric light with a focal intensity of about 120,000 candle-units was practically available, namely, four superposed arcs of about 30,000 candle-units each. Such a light could be provided at a total cost per focal unit of light of about 1*s.*, being about $\frac{1}{48}$ of the cost per focal unit of the original electric light at Dungeness. It was also demonstrated that about 10,000-candle compact focal-flame light was practically available in four superposed luminaries, and could be produced with mineral oil at a present cost per focal unit of light per annum of about 2*s.* 7*d.*, or about $\frac{1}{20}$ of the former cost per focal unit for a first-order oil lighthouse. A light of 10,000 candle-units was rather more than treble the focal intensity of the Souter Point electric light, which had given satisfaction to mariners for sixteen years. He was not aware of any electric light installation at home or abroad, of about 10,000 candles focal intensity, maintained under 3*s.* per focal unit of light. The reduction, therefore, of the cost of installation and maintenance of electric lights of moderate intensity, as suggested by the Author, was a matter demanding careful consideration. With reference to the caloric engines introduced in 1871, when no other safe, efficient, and economical small motors were available for placing under the charge of untrained keepers, and in the absence of fresh water, those engines had done a great deal of good work for many years, especially with fog-signals. The engines were cumbrous, and in that respect they compared unfavourably with steam- or gas-engines. A large portion of the work was taken up in com- Sir James Douglass.

Sir James Douglass. pressing air and in friction. The average consumption of fuel was about 3 lbs. of best locomotive coke per brake HP., and for an engine of 10 HP. that must be considered very moderate. In the Author's experiments at Birmingham, the amount was 4 lbs., but the inferior gas coke used accounted for the difference. The last, but probably not the least, important part of the question, suggested by the Author, was under what circumstances, if at all, electric light should be used in lighthouses. That question was fully considered by the Committee of Trinity House who conducted the recent South Foreland experiments on the relative merits of electricity, gas, and oil as lighthouse illuminants, and the well-known conclusions at which they arrived appeared to be endorsed by all the leading lighthouse authorities of the world, namely—That with regard to the efficiency of gas and mineral oil luminaries for lighthouses, there was no practical difference for the purposes of the mariner, but that mineral oil was the most suitable and economical illuminant, and that for salient headlands, important landfalls, and places where a very powerful light was required, electricity offered the greatest advantages. Engineers now knew precisely how they stood with regard to the relative efficiency and economy of flame and arc lights for lighthouses; they also knew that electric light was far more efficient than either of its competitors where the highest intensity was demanded, and that under those conditions it was the cheapest per unit of light produced. There appeared, therefore, nothing more to be desired. It was well, however, to consider the economical applicability of electric light for smaller installations, where a moderate intensity was required. The present competition between flame and electric light was therefore now limited to cases of moderate intensity, and strict economy; but where money would be found for an important position like a landfall, no one could say what intensity of electric light might not be placed there. Both electric and flame light had been proved to be capable of intensities far beyond anything that could have been anticipated a few years ago. With flame light the maximum might fairly be considered to have been reached at the South Foreland, but with electric light it was impossible to say that the present focal intensity of 120,000 candles might not be exceeded in a few years, as much as the 120,000 exceeded the original 670. With regard to the use of the gas-engine with Dowson gas in the closed apartment under the lantern of a lighthouse, he would be glad if the Author or Mr. Dowson would explain how he would prevent the light-keeper being injured

by escape of carbonic oxide from the engine. The light-keeper must be occupied throughout his watch in the engine-room and lantern immediately above it, these apartments as regarded their ventilation being practically one. Sir James Douglass.

Professor W. GRYLLS ADAMS observed that the Author had stated that the justification of his communication was, that at Macquarie and at Tino the optical apparatus was on a larger scale than had hitherto been used for electric arc in lighthouses. He thought that no justification, beyond its own excellence, was needed for the Paper. Sir James Douglass had already referred to the size of the apparatus used for electric light in lighthouses, and the matter was one which could not be too much emphasized, because he feared that in the past, sufficient attention had not been given to the fact that, when electric light was to be employed for lighthouses, the light was so much more powerful than any other, that the second- or even the third-order system of lenses was considered sufficient, it being perhaps overlooked that the larger or first-order lenses might be better. There was one great advantage in electric light, which perhaps did not necessitate a large apparatus so much as other lights, namely, its great concentration. It was concentrated into a very small space, especially was this so in the earlier lights with small carbons, giving literally only a point of light. In the case of the larger carbons, the light was not confined to one point, but might fly across a succession of points at the edge of the crater, at some little distance from the focus of the optical apparatus. In using larger carbons it was of course the more necessary to have a larger optical apparatus. With that larger apparatus a greater quantity of light might be concentrated in a particular direction, so that if it was required, say on the horizon 20 miles distant or more, a much more intense beam might be obtained. But with carbons such as were now used with the larger optical apparatus, there was this additional advantage, that the points from which the arc flew being a little out of focus, the beam of light would spread more. It had been stated that with gas lights it was advantageous to have a widely divergent beam. Should that be required, it would be easy in the case of electric light to slightly contract the size of the apparatus. The arc in the centre would be not quite in the focus of the optical apparatus, but the lenses would be a little nearer to it all round, thereby producing a slight divergence of the beam. With a powerful light, and a first-order optical apparatus, while that object would be secured, there would still be a very powerful beam extending to the horizon. Then again, by slightly Professor Adams.

Professor Adams. shifting the position of the arc a little above the position of the focus, it was possible to get a beam of light slightly divergent, which should illuminate the sea from the horizon to a point very near the lighthouse, and he thought it probable that there might be cases in which it would be advantageous so to use the electric light in some lighthouses. There were one or two other points alluded to by the Author, in which he thought that his determinations at the South Foreland agreed remarkably well with the results given in the Paper. In the photometric experiments made upon the arc, the Author's method of measuring the intensity of the illumination by means of ruby glass, and by a solution of sulphate of copper and ammonia, was the same method which he himself adopted at the South Foreland, for measuring the intensity of the red and the blue light through those substances from the electric arc. He observed that the Author had obtained about 2,000 red candles when the machine was at half power, and about 4,000 blue candles. The intensities of red and blue from electric light were very nearly in the proportions of 1 to 2. Referring to the report which Professor Adams had communicated to Trinity House, as to the intensities of the light at the South Foreland, using one machine, he had a light of 8,000 red candles and 16,000 blue, the proportion being the same as in the Author's experiments. Again in making use of two machines he obtained 13,000 red and 23,000 blue, and with three machines 16,000 red candles and 31,000 blue, the proportions being pretty nearly the same as those given by the Author for the relative intensities of illumination of those two kinds of light. When the current in the arc was greatly increased, the blue exceeded the red in a greater ratio than 2 to 1. The Author had spoken of the glare of electric light upon the sky being seen far beyond the distance at which the light would cease to be directly visible. On one occasion, during the experiments at the South Foreland, the electric arc was placed a short distance below the focus of the lens, so as to raise the beam above the horizon and throw it on the sky and clouds. The revolving conical beam, passing over the head of the observers and over Ramsgate, caused an illumination on the sky which was seen at points on the Essex coast not far from Harwich, and gave the impression to the coastguardmen, who were not warned of the experiment, that there was a ship on fire away beyond the horizon to the south. In this case the distance at which the light was observed was about 40 miles. On another occasion at the South Foreland, he was observing the light of the electric arc from the Calais lighthouse at a dis-

Professor Adams.

tance of more than 20 miles. Its very great brilliancy was shown by the fact that a telegraph-post at St. Margaret's Bay cast a distinct shadow on a sheet of paper when the revolving beam of the Calais light fell upon the post. The Author had suggested a simple and very pretty method of changing from one dynamo and engine to the other. The method depended upon the fact that two equal alternate-current machines, when connected separately to the same circuit, and revolving at the same rate, would run together as though they were mechanically coupled, and each would tend to control and govern the other. When the machines were running together at full speed, the belt might be thrown off one and it would continue to run in harmony, being driven as a motor by the electric current from the other. On putting the brake upon the motor, the speed of the motor would be diminished; it took more current from the generator, and the electromotive force would be lowered. Thus, in the experiments by the Author and himself on the machines at the South Foreland, a weight of 28 lbs. upon the brake, consuming more than 2 HP., lowered the electromotive force on the generator from 80 volts to 78 volts; with a weight of 42 lbs. on the brake, the electromotive force was reduced to 76 volts; and with 56 lbs. upon the brake, the electromotive force was reduced to 74 volts, and the two machines continued to synchronize at the lower speed. In this case the work done upon the brake was equivalent to more than 4 HP. On driving one machine as a motor, by means of the current from two others, both used as generators of electricity, the electric arc burnt more steadily than when the three machines were driven independently; the third machine when driven as a motor acted as a governor and controlled the other two machines. The Author had spoken of the efficiency of lighthouse lights being measured by the fewness of the occasions when they failed to penetrate their normal range. Tested by this means, the superiority of electric light for lighthouse work would be at once apparent.

A comparison of electric and oil lights of the first order was made by Mr. Petit, Hydrographer to the Belgian Government, some years ago, soon after the electric light was permanently established at the South Foreland. He estimated the relative efficiency of the electric light of 1,200 candles and the oil light of 300 candles, and found that on seventy-six nights in one hundred the electric light was seen at a distance of more than 20 miles, whereas the strongest oil-lights then used were only seen on twenty-nine nights in one hundred at the same distance. Improvements had

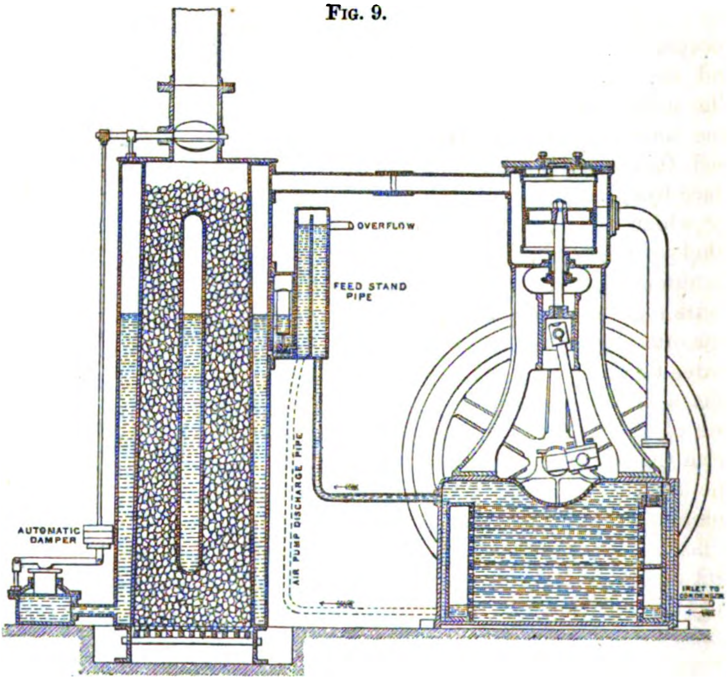
Professor Adams. been made in oil-lights by adding extra rings of wicks, bringing the candle-power of the 6-wick oil light up to 730 candles, and increasing the cylinder of flame to about 4½ inches in diameter. In the meantime gas had also been introduced for lighthouse use, and, by the addition of ring after ring of burners, the largest gas lights regularly used consisted of 108 jets, giving a light of 2,400 candles, and a cylinder of flame 11 inches in diameter. The oil light, 4½ inches in diameter, yielding a light of 730 candles, and a gas light, 11 inches in diameter, one of 2,400 candles, would emit beams of light more and more divergent as the source of light was larger, and as seen from any point in the axis of the beam would appear of equal brilliancy; when placed behind a very powerful lens they were nearly equal in brilliancy to the electric light of 1,200 candles in the permanent lighthouse, which for the last fourteen years had been supplied from the Holmes magneto machine, and in the observations made on the sea these three lights had been seen over the same range. Following Mr. Petit, it might be said then, that both oil and gas had so improved, that the practical efficiency had been raised to 76 per cent. But the efficiency of electric light did not stop at 76 per cent., the value given by Mr. Petit as the practical efficiency of the permanent electric light supplied for the last fifteen years by the Holmes machine. If the efficiency of this light be compared with electric light from the De Meritens machine, by means of the electric currents which severally produced them, in the first there would be found a current of 30 amperes, giving an illumination of from 1,200 to 1,500 candles; and in the second, a current of from 120 to 150 amperes, yielding a light ten times the power, of from 12,000 to 16,000 candles. The effect of this increase of light would be to render this light visible at sea at a distance of 20 miles, through hazy atmosphere, on from eighty-eight to ninety out of every one hundred nights in the year. Thus the increase in the illuminating power which was possible with electric light diminished the risks to shipping, and raised the practical efficiency of lighthouse lighting from 76 per cent., the best that could be done by any other means, to 90 per cent., leaving only ten nights in a hundred when the light was not seen 20 miles away. By a proper arrangement, and more powerful lenses, the efficiency could be still more increased.

Mr. Davey. Mr. Henry Davey said he was pleased with the record of a hot-air engine which did a better duty than the majority of such machines, giving a consumption of about 3 lbs. of coke per brake HP. The small hot-air engines of from ½ to 1 HP., generally

used for pumping purposes, were not so economical. He supposed Mr. Davey. that the economy to which he had referred, was partly due to the fact that the engine was so much larger, and partly to the use of an air-pump. But he thought that there were certain objections (some of which had been mentioned) to the use of hot air. The engines were difficult to govern, they were not automatic, and they required frequent and careful stoking. A gas-engine was of course perfectly automatic, but it was not always applicable; when gas was not supplied, it could only be used by means of special plant for the manufacture of the gas, which of course increased the complexity of the machine. With those facts before him, and seeing that small air-engines did not give so high a duty as an ordinary steam-engine, he had for some time past tried to produce what might be called a perfectly automatic steam-engine; and in order that the engine might be free from danger, he had used negative pressures, working with steam at atmospheric pressure. He had made a considerable number of such engines from ½ to 10 HP. He had started with the idea, that a small motor for general purposes to which small motors were applied, should require very little stoking, and with that object he had devised a boiler to which he had given the name of a hopper-boiler. This consisted simply of a reservoir for water and a reservoir for coke, the annular space shown in Fig. 9 forming the water space, and the central cavity the coke space. In a vessel 5 feet 6 inches high by 2 feet square he had been able to produce a boiler which would give 4 HP. on the brake and run eight hours without stoking. The firebox of the boiler was made slightly taper to prevent scaffolding of the coke. The grate-area was not sufficient to maintain combustion beyond a certain height, called the incandescent zone; the products of combustion beyond that point had to find their way through the interstices of the fuel in which the heat became absorbed. So completely was the heat utilized, that when the fuel was burned down about half way in the boiler, it was possible to take off the top of the hopper, and remove the lumps of coke by hand. That conclusively showed that there was not much waste heat going away in the products of combustion. His only fear had been that a large amount of carbonic oxide was escaping, and he was surprised to find that such was not the case. With a boiler of that kind working at his own house over two years, he had repeatedly tried to produce a flame at the top, by lighting the carbonic oxide escaping with the products of combustion, and he had never succeeded, so it was evident that only a very small portion of carbonic oxide was

Mr. Davey. produced. The motor itself (Figs. 9 and 10) possessed nothing very peculiar. It was merely a low-pressure steam-engine with an ordinary slide-valve cutting off steam at about half stroke, without

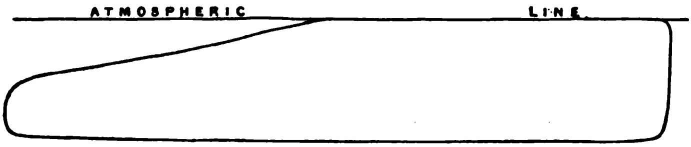
Fig. 9.



Davey Safety Motor and Hopper-boiler.

Scale 0 1 2 feet.

Fig. 10.



Indicator Diagram from Davey Safety Motor.

Average pressure = 10 lbs. per square inch.

any expansion-valve, and producing a mean effective pressure of 9 lbs. per square inch of the piston. Looking at the drawings of the Brown hot-air engine, he found that the cylinder capacity in an engine of that construction was only one-third that of the air-

engine, so that an air-engine became a much larger and more bulky machine than the other, notwithstanding the low pressure. The difficulty in the application of a motor of that kind for lighthouse illumination would be, in a large number of cases, a want of water; but where sea-water was obtainable the case was quite simple, because the condenser of the motor was a surface condenser, and the sea-water could be circulated through the condenser. The motor was so constructed, that the water used in the engine was condensed, and was returned to the boiler, so that the only feed that the boiler required was any waste which might take place from leakage. It might be of interest to show the method by which the water-level was maintained in the boiler, and the whole of the condensed steam returned to the boiler automatically. So automatic was it that it might, with perfect safety, be left for hours together without any one coming near it. His own engine was often left with the door locked for five or six hours, and the water-level scarcely varied $\frac{1}{8}$ inch. On the side of the boiler was a little stand-pipe, divided into two compartments. Into one of the compartments the overflow, or the circulating water from the condenser, passed; into the other the distilled water from the air-pump. The distilled-water compartment was in free communication with the boiler through a pipe controlled by a float. The two water-compartments—one with distilled water, and the other with the circulating water—were in communication only by means of a very small hole through the partition. The water-level of the vessel was a little higher than the water-level of the boiler. Now it was evident that if there was a leakage between the air-pump and boiler, or in the boiler itself, the water-level would tend to fall, because the quantity of water delivered back to the boiler was less than the quantity of water that left it. When that occurred, the water-level in one part of the divided stand-pipe would be a little below the water-level on the other side of the partition, and water would then flow in from the other side through the small hole, to make up the deficiency; so that the deficiency was automatically supplied. With the use of salt-water for circulating in the condenser, it would be necessary to supply the leakage from the ordinary fresh-water supply of the establishment. Besides this form of automatic engine, he had also produced for purposes of small power another without a condenser. That was where condensing water was not available. The method was to use the hopper-boiler—to make it cylindrical to resist pressure, and to put in connection with it a reservoir of Mr. Davey.

Mr. Davey. water holding eight hours' supply. With a full supply of water and of coke, it ran for eight hours automatically.

Professor Forbes. Professor GEORGE FORBES remarked that the first part of the Paper had reference to the optical arrangements adopted in the lighthouses referred to, and every one would agree that Mr. James T. Chance was to be congratulated on the idea which he had originated, of concentrating the light on different parts of the sea, by means of different portions of the optical apparatus. The conclusions in the Paper, as to the performance of that system, seemed thoroughly to warrant its adoption on a more extended scale. In spite of the very small quantity of light which was deflected on the near parts of the sea, it appeared more than sufficient, and it seemed that in further extensions of the system the Author would be inclined to recommend even a smaller quantity. The only other part of the optical apparatus on which he would remark was the dioptric reflector. Any reflector had of course the disadvantage that it had to throw the image of the light upon a side point, not directly on the main focus. The consequence was that the lighthouse had two points of light illuminating the area, and he wished to ask whether there was not sometimes a double maximum of light in a revolving lighthouse, due to those two points, which were serving as points of illumination? Probably most members who had watched the behaviour of an electric lighthouse must have noticed sometimes the appearance of a double flash. He had never known to what cause that ought to be assigned; but it was probably due to the double image produced by the reflector. It was particularly noticeable either when the flash was red, or in foggy weather, when it was like two distinct flashes. The Author's views as to the adoption of large-focus high-order lighthouse lenses for the arc light were to be highly commended, not only for the reason given by Sir James Douglass, that the sputtering of the carbon was injurious to a small apparatus like that of Dungeness; but, as had been pointed out by others, because with a small apparatus the whole benefit of the concentration of electric light in directing the optic beam was taken away. The Author had drawn attention to the choice between alternate-current machines and continuous-current machines. As a matter of fact, there were three classes of machines of which the engineer had the choice. First, there was the continuous-current machine, which was supposed to labour under the disadvantage of having a commutator with its brushes, which were at one time liable to serious sparking. In the second place, there was the alternate-current machine, fed or excited by means of a continuous-current machine. The exciter in this case

was liable to the same objections as in the direct-current machine; but the alternate-current machine in itself was free from the defects of brushes and commutator, and there was no sparking at the point where the current was taken off from the alternate-current machine itself. In the third place, there was the alternate-current machine, with permanent magnets, which had been generally, if not exclusively, used where alternate-current machines, such as those made by Baron De Meritens, had been employed in lighthouses. Since in the last-mentioned machine the magnetic power was comparatively feeble, owing to the employment of permanent magnets, its size was necessarily much greater than that of others; it was therefore a more expensive machine than either of the others; but it had the advantage which had been claimed for it of steadiness. The large mass of the revolving armature acted, to a great extent, as a fly-wheel, and undoubtedly tended to counteract any slight irregularity in the governing of the steam-engine. It was also free from the objection, which was a valid one some years ago, that might be raised, to the use of a machine with a commutator and brushes. There was no commutator, and there were no sparking brushes. The whole machine was complete in itself, with simply a rubbing contact and a continuous mass of metal. In former times, when tests were made of continuous-current machines for lighthouses, this kind of machine was not nearly so perfect as at present; there was violent sparking, and occasionally excessive burning away of the brushes; at the same time the commutator of the machine was also much burned, and repairs were more frequently required than at present. The continuous-current machine was now thoroughly reliable for long periods of service without requiring repair. But as that was the case, all objection to the alternate-current machine using the exciter was removed. It was superior to the alternate-current machine of De Meritens, because in the first place it was not so cumbrous, not so large, nor so costly, and it was equally steady when governed by a sufficiently large fly-wheel. The Author had stated that the direct-current machine had the advantage of being not only more compact, but also less costly. It certainly was the most compact form known, and consequently it was suitable for a contracted space, such as the interior of a lighthouse. It was certainly less costly than the De Meritens machine, but he doubted whether it was less costly than the alternate-current machines fed by a continuous current. In this country, the production of those machines had been very limited, being confined to a very small number of makers. In America, Professor Forbes.

Professor Forbes.

they had lately been largely manufactured, and it might surprise members to hear that alternate-current machines were being manufactured in America, with the exciting machine included, at a total cost of £1 10*s*. per HP. The alternate-current machine then was far the cheapest in construction. But there were other differences between the two classes of machines. The continuous-current machine produced a crater at the positive end of the carbon, of an intense brilliancy; whereas on the negative carbon there was a protuberance. There was thus no uniform distribution of light in a vertical plane such as there was with the alternate-current machine. This latter gave a crater at the point of each of the carbons, but very much modified. Neither of the craters on the carbons of the alternate-current machine were so large or deep as the crater of the continuous-current machine. Sir James Douglass had shown the fluted carbons that he used in order to avoid the production of craters with the alternate-current machine. He had told him that he had not tried them with a continuous-current machine. It would be extremely interesting to know whether with those fluted carbons the crater was done away with in a continuous-current machine. It was pleasant to notice in the Paper a thorough enunciation and appreciation of the different conditions which existed in different lighthouses, and the different classes of machinery required. Undoubtedly each special case needed special attention. The latter part of the Paper was that which naturally invited discussion more than the rest—that in which the Author had stated what results had been derived from the experience of electric lighting of lighthouses, and what might be expected in the way of future development. In order to illustrate that point, he had taken the case of a special lighthouse, and had proposed to adopt a certain system of apparatus. His system was no doubt admirably suited for the requirements. He had stated that "The essentials for a cheap electric lighthouse are, that for ordinary states of the atmosphere there shall be provided a plant under the easy control of the light-keeper himself, which shall be precisely adapted to produce that amount of light which is wanted in ordinary states of the atmosphere; but for thick weather there shall be provided a much more powerful engine and dynamo, available also as a reserve in case the smaller machinery from any cause breaks down." For ordinary work it would be observed that a similar dynamo and lamp were used, and for exceptional cases in thick fog a more powerful apparatus was required. The Author had mentioned the use of secondary batteries in the single sentence "Accumulators could be used."

Professor Forbes.

He thought the Author had rather overlooked the advantages which might be derived from accumulators or secondary batteries in such an installation as he had proposed. Evidently since the large and expensive part of the apparatus was to be employed only in thick weather, it would be possible to replace it by a secondary battery of great power, which should be used at all times; and which should be continually accumulating a reserve for thick and foggy weather, likewise acting as a reserve in case of accidental injury to the dynamo. In that way not only would the plant be under the direct control of the light-keeper himself in clear weather, when he had a small dynamo at work, but it would also be under his direct control during thick and foggy weather. In fact, the attention of the man looking after the lantern need be disturbed by no consideration as to the performance of the engine and of the dynamo. The battery would work the lamp, and he might be pretty sure of its safe and continuous action during the period that he was looking after it. The dynamo charged as a secondary battery should be at work not during a limited period, but during as long a period, day and night, as the attendant at the lighthouse could afford; and thus a comparatively small dynamo, perhaps very little larger than the small one recommended by the Author, might be used to charge the secondary batteries, not only during the daytime, but also while the service was going on, and while the lights were in use. Whether simply as a reserve, or as facilitating the labours of the lighthouse keeper, it seemed clear that the use of the secondary batterios deserved somewhat more attention than perhaps had been given to the subject in the Paper. The Author had stated, "The lighthouse keeper again must understand a gas-producer, a gas-engine, a dynamo, and an arc lamp." Perhaps it would be too much to add that he should understand a secondary battery; but no doubt the Author would agree with him that secondary batteries had now reached such a stage, that if a man was subject to discipline, as a lighthouse keeper undoubtedly was, and if he would attend to the strict rules laid down for him, the performance of the battery might be looked upon as perfectly reliable. That was the chief point to which he wished to draw attention—the use of secondary batteries in lighthouses.

Mr. Crompton.

Mr. R. E. Crompton entirely agreed with the Author as to the great desirability of trials being carried out with continuous-current machines, and he also agreed with Professor Forbes as to the ground on which they had been temporarily condemned

Mr. Crompton. a few years ago. Those causes had now disappeared. Seeing that nineteen-twentieths of the electric lighting of the world was carried on by continuous-current machines, and when all the improvements and advances in those machines were borne in mind, it would, he thought, be admitted that there was a great deal in the Author's contention. He had intended to enlarge considerably on what Professor Forbes had brought before the members as to the employment of accumulators, which was only possible as a reserve when using continuous-current machines. His own experience had led him to believe that a continuous-current dynamo machine, running parallel to a set of accumulators, was the safest and most certain source of supply of the electric current. He agreed that accumulators were good enough to be put into the hands of any intelligent lighthouse keeper. A great deal that had been said about accumulators and their failures might be attributed to the fact, that far too much had been expected of them. Very strong currents had been taken out of accumulators that were not intended for powerful discharge, and the result was that they had been damaged, and their performance had fallen off. For this purpose, however, there was this one comforting fact, that whatever the performance of accumulators might be, the falling off of efficiency was very gradual, and could be noted from day to day; there was no sudden breakdown, but ample time was given for lighthouse keepers in most situations to report such gradual failure, and to replace defective cells by cells kept in reserve. One great advantage of an accumulator was that only one dynamo could be used. An improvement on the arrangement proposed by the Author might be suggested. Instead of a small gas-engine with a small dynamo for ordinary purposes, and a larger gas-engine with a larger dynamo for fog service, the dynamo might be rather larger than the small one proposed by the Author, which would charge the accumulators—charging them parallel to the light that was burning, and whenever fog came on, without any change whatever, except the exchange of the lamp, the powerful current would be used direct from the accumulators. This would make the apparatus simpler than the one proposed by the Author, and the cost would be rather less. The cost of the extra engine and dynamo would be represented by the cost of the accumulators themselves. He wished to point out how the objections to continuous-current machines could be overcome. A parallel case occurred to engineers when designing any large installation, where large machines had to be excited by small ones. In such

Mr. Crompton.

a case the failure of the exciting dynamos meant the failure of the whole installation. He had overcome that difficulty by not exciting with one dynamo but with two dynamos parallel, each being big enough to do the whole work of exciting for a reasonable period. He had thus two strings to his bow. If one dynamo went wrong there was always another to continue the work. That secured entire immunity from breakdown. With reference to the crater formed on the positive carbon, Professor Forbes had mentioned it as a disadvantage. Of course it was a disadvantage, yet only so long as the present dioptric system was followed, which was intended for alternating currents. He could not admit the disadvantage of the crater if the necessary distortion of the prisms was calculated, so that the powerful downward beam from the crater could be properly utilized. He thought it would naturally suggest itself to the Author that this should be done by rearranging the separate prisms, so that he should take that portion of the light that fell from about 15° below the horizontal line, down to, say, 75° below the horizontal line, and employ it for the horizon lighting, using all the remainder above the 15° below the horizontal line up to the extreme point, which was 65° above the horizontal line, for the near sea light. It appeared to him that, unless there were great difficulties in the way, a far simpler method of using a continuous-current arrangement for revolving lighthouses would be to resort to the old catoptric arrangement. The Author had put some work into his hands nearly two years ago — the lighting by electricity of a light-ship intended to be placed at the station at the mouth of the Mersey. He had there the difficulty of establishing electric light on a light-ship mast. He could not use the dioptric arrangement, because the mast came in the centre of the lantern, which had to be raised and lowered. Instead, therefore, of the arrangement of one lamp, four lamps were employed, each lamp having a catoptric reflector behind it, and these were placed symmetrically round the lantern. In that case there were four continuous-current lamps carried in gimbals, so that they could swing with the motion of the vessel, or rather, keep their vertical position notwithstanding the rolling of the ship. The lamps faced away from the horizon, in other words they faced towards the mirror, and the direct rays were shielded from the horizon by a little shield. The lamps were canted back at an angle of 30°, and the upper carbon descended in a line parallel to that of the lower carbon, but somewhat nearer to the little shield. Thus the crater was not formed exactly under the upper

Mr. Crompton. carbon—not on the axial line, but somewhat to one side, and facing the main mirror. The result was that three-fourths of the illuminating power of the positive crater was directed as required, namely, against the main mirror. The arrangement had worked very well, and the light-ship would have been on the station, but for the fact that the character of the flashes coincided too closely with that of another light-ship, so that it was dangerous; and the number of flashes was now being altered. The great difficulty in cases of that kind had been to keep the lamps tolerably steady, and the reflectors directed towards the horizon when the ship was rolling, in the way a light-ship did roll when moored. The ship had already gone through various trials, and the result had been satisfactory. There was no doubt much to be done before securing steadiness in any way approaching that of a light from the land. Unfortunately there was a difficulty in getting over the dazzling effect near at hand. Two of the four lamps were worked parallel from one machine, and the other two from another machine, each machine being driven by its own separate high-speed engine, and the arrangement being worked by duplicate boilers. There was a revolving gear not actuated by the ordinary clock-work arrangement, but by worm-gear from the shafts of the steam-engine. The system was considered a novelty, but the result had been satisfactory. Another interesting point about the vessel was, the utilization of the simple arrangement, often used in river launches, for condensing the exhaust steam by carrying it through outside pipes placed close to the bilge keels, thus forming a simple surface-condenser cooled by the tidal current, allowing little or no escape of the steam, which was a serious inconvenience when it occurred near the lantern. Every one knew what a conspicuous object steam was when illumined by the rays of electric light, and how confusing and dazzling it might be. No doubt some of the Author's deductions might be criticised, namely, those in which he had given a comparatively high candle-power for such a small current as 20 amperes (which was the current he proposed to use), when he wished to produce an electric light to compare fairly with an ordinary oil- or gas-lighted lighthouse lamp. He was quite certain that the Author had been speaking very cautiously, and well within the mark, in stating that 1,200 candles in red light might be obtained from 20 amperes worked by a continuous current. When Mr. J. E. H. Gordon was writing a book on electric light two years ago,[1] Mr.

[1] A practical treatise on Electric Lighting. 1884.

Crompton made a series of experiments for him, and obtained results very greatly in excess of the Author's, so much so that he hardly liked to quote them; but he was quite certain that fully 1,800 candles—50 per cent. more than the Author's figures—could be obtained from 20 amperes under those conditions. Mr. Crompton.

Mr. Gisbert Kapp said that the Author had stated that two dynamo machines, of the same type as those used in the Tino lighthouse, could be coupled parallel. It was satisfactory to be able to refer to a case in which alternate-current machines were being used so coupled. Hitherto that conviction had been only a theoretical one, except in the case of Mr. Wilde's experiments. The Author had explained the theory that machines could be so worked; but, as far as he knew, the method had not been tried until it had been adopted in the lighthouse at Tino. It was a matter of importance, because, not only for lighthouses, but for other places where electric light was introduced, alternate-current machines were coming into fashion; or he might rather say, the employment of alternate-current machines was being forced upon the electric-lighting engineer, when he wanted to carry light to any distance by transformers. But if the distribution was effected by means of feeders and a network of mains, it was necessary to be able to put on more machines, or to take machines off, as the consumption of electric light in the network varied; and of course, if it were not possible to work those machines in parallel, it would be impossible to equalize the potential all over the mains. It was easy to understand that machines coupled, not only electrically, but also rigidly coupled mechanically, should be able to work so that their currents might be added. All that was necessary, was so to place the coupling, that the armatures should occupy corresponding positions in their magnetic fields. It was also easy to understand that if the mechanical coupling was extremely flexible, the two machines would synchronize. When two dynamos were driven by two engines working with some kind of elastic fluid, such as steam, or gas, or hot air, a racing machine would have a tendency to do more work than a lagging machine, and would run a little slower to give the latter machine time to come up. But consider the case in which the coupling was not absolutely rigid, and not absolutely elastic, as in belts. Although it was not explicitly stated, he supposed that the arrangement at Tino was by means of a countershaft and two belts, one belt to each dynamo. If it were possible to make quite sure that the pulleys should be exactly of the same size, and that the belts should be put on with the same tension, equally flexible and equally thick, Mr. Kapp.

Mr. Kapp. the arrangement would act almost as well as a rigid coupling. But it was hardly to be expected that the machines should start with their armatures in equivalent positions, and the question was whether in such cases it was possible that one armature should creep up to the position which it ought to occupy in comparison with the other. On the other hand, it was not probable that the belts would be of equal tightness, or of equal flexibility, and the pulleys might be slightly different. In that case there would be a tendency to a divergence of speed, and the racing machine would have to supply some current in order to correct that tendency. He would ask the Author what he considered the limit of divergence in speed, and whether there was any serious loss from that cause. In the suggestions thrown out by the Author for erecting a lighthouse, he naturally adopted continuous-current machines. Professor Forbes and Mr. Crompton had already referred to the machines used at the Lizard for experiments with the continuous current, which he was afraid must be acknowledged to have been a failure. He could not agree with them in putting the blame on the dynamo; he thought it should be placed on the engine. When a hot-air engine was used, the government was necessarily very sluggish, and unless a dynamo was perfectly governed it could not be expected to light a single arc lamp. The greater the number of lamps in circuit the easier it was to obtain steady arcs; but the lighting of one lamp alone was the most difficult work that a motor could perform, and unless it was perfectly governed it would "hunt," the arc would lengthen and shorten, and it would be impossible to keep the light steady. In adopting continuous currents the lamps had to be tilted, as in the case of the search lights in the Navy, where large currents of 150 amperes and more were used. If the carbons were tilted and put a little out of alignment, in order to get the crater well forward, it would be necessary to provide a somewhat more complicated adjustment in order to focus the lamp. In the arrangement shown in Plate 9, Fig. 18, the adjustment was only in a vertical line, whereas, if the carbons were tilted, the adjustment would have to be not only vertical but also horizontal. He did not think, however, that that would be a very great difficulty, and it certainly was not the reason why alternate currents had been used alone up to the present time. He was afraid the real reason was that lighthouse engineers had no confidence in continuous-current machines. It had been often said that the magneto alternate-current machine was absolutely safe, and the statement was true. Almost anything might be done with such a machine.

It might be short-circuited, and it would not come to harm; the circuit might be broken entirely, and it would not run away. In fact, a magneto machine with alternate currents might be compared to a steam-engine, the fly-wheel of which ran in a pit filled with treacle, and the steam-pipe of which was about one-tenth of the size it ought to be. If in such a case the load were put on suddenly, it would not make much difference, because there was so much internal friction already, that the additional load would be comparatively small. And again, if the load were taken off suddenly, the engine could not run away, because the friction of the fly-wheel held it back, and the inlet of steam was so small, that the pressure of the boiler would be much reduced in getting the steam through the pipe. Such a steam-engine would be extremely safe, and would never fail, but it was very doubtful whether any one would care to use it. In the alternate-current machine the magnetic field was very weak. He had the figures of one machine, namely, 4,920 for the induction in the armature, whereas modern continuous-current machines were very easily run at 18,000 and even 20,000 in the armature. The self-induction was very large, and the resistance of the armature was great in comparison to the electromotive force, and hence the machine was not injured when short-circuited. But its efficiency was low, and it occupied a great deal of space. A continuous-current machine would probably give 20 or 30 per cent. more efficiency, and occupy much less space. In considering the question of the reliability of modern dynamos, there was very little difference between the alternate-current and the continuous-current machine. It had been often stated that it would not be wise to rely on a piece of machinery in motion for electric light, but as a matter of fact dynamos did not break down. In New York, in Milan, and in other towns, installations had been in existence for several years. The pressure had never been off the wires for a single instant, day or night, and there had never been a failure, the consumers having always had light when they wanted it. It was evidently much easier to control a single dynamo with a single lamp, than a complex system of many dynamos with a very large network of wires and lamps, placed under the care of persons totally unacquainted with the science of electricity, and often unacquainted with the ordinary precautions dictated by common sense. Yet it was possible to work such installations without serious inconvenience, and with absolutely no interruption in the light. In Germany and in Austria alone twenty theatres were now lighted entirely by electricity. Most of those theatres employed accumulators and Mr. Kapp.

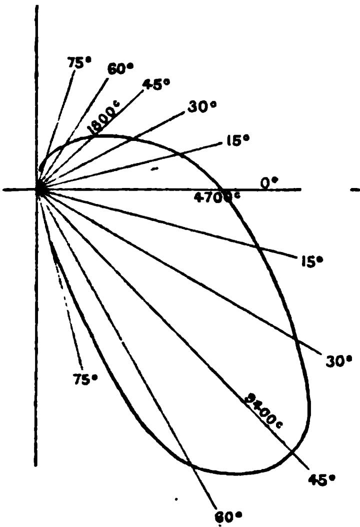
Mr. Kapp. continuous-current machines. If there were the slightest chance of the light failing, the calamity would be enormously greater in a theatre than in a lighthouse; yet the authorities had perfect confidence in the continuous-current machines adopted in theatres. He could not agree with Mr. Crompton, who recommended a gas-engine, a dynamo, and an accumulator. It was true that in that way there was a reserve, but only for a limited period, because accumulators could not be charged to an unlimited extent, and if the dynamo should break down the accumulator could not be recharged. If accumulators were used at all, they should be used in connection with two dynamos, and not one only. He hoped that the suggestions which had been thrown out in the Paper, with regard to continuous-current machines, would lead to their actual use. Machines of this type made in England were certainly superior to any manufactured elsewhere, and he thought that in future, lighthouse engineers would not go to France for their machines, but would get them at home.

Mr. Shoolbred. Mr. J. N. Shoolbred remarked, that although the Paper was generally of great interest, the principal fruit to be expected from it lay in the concluding suggestions, as to the introduction of continuous-current machines in lighthouses. This class of dynamo was supposed to labour under two disadvantages: first, that the machines were less reliable in their constitution than the alternate-current machines; and, secondly, in regard to the character of the light emitted, that it was not so easy to handle and make use of. It was to the latter point that he wished to address himself. He had endeavoured first of all to ascertain, whether there was any relative record of facts with regard to the alternate-current machines under discussion, as against continuous-current machines. In none of the numerous and careful experiments, in 1876–77 and in 1884–85, at the South Foreland, was the De Meritens machine brought into comparison with any of the others; but, in France, Mr. Allard, the Engineer-in-Chief of French lighthouses, had carried out in 1880 a series of comparative experiments[1] between a De Meritens machine of almost the exact size described by the Author, and a Gramme machine, which was near enough for comparison. Among the experiments were a series of photometric measurements of the intensity of the light, taken at various angles in the vertical plane. The result of those experiments was shown in Figs. 11 and 12. The Gramme curve represented the curve of maximum intensity of the continuous-current machine; and

[1] "Mémoire sur les Phares Electriques." Par M. E. Allard. p. 83. Paris 1881.

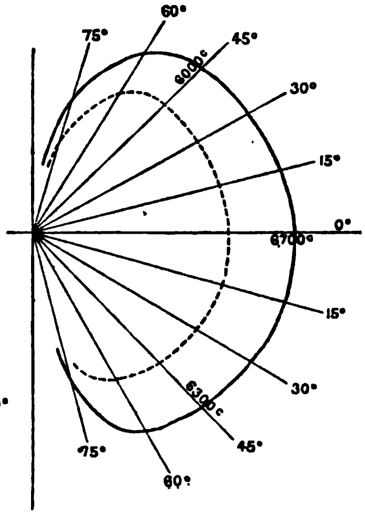
the De Meritens that of the alternate-current machine. The extreme difference in the nature and in the direction of the rays would be at once seen. The argument of the upholders of the alternate-current machine was, that the resulting curve was much more easy to handle and to project forward than was that from the continuous-current machine. Undoubtedly it was so, as it was primarily emitted; but surely some arrangement of lenses could be made, by which the lower portion, below the horizontal, on the continuous-current curve could be made use of and projected forward. Mr. Allard had found that with the continuous-current Mr. Shoolbred.

Fig. 11.



Gramme.

Fig. 12.



De Meritens.

Scale 5,000 candles = 1 inch.

Gramme machine there was an expenditure of 6 HP. as against 8 HP. with the alternate-current De Meritens machine. The dotted curve inside the curve of the latter, was the proportionate one which might be expended from a consumption of 6 HP. with this machine. The HP. efficiency was found by Mr. Allard to be in favour of the continuous-current machine, a mean intensity of 860 candles per HP. as against 800 with the De Meritens machine. In addition to this, economy in prime cost would certainly be in favour of the continuous-current machine. The cost of the De Meritens machine experimented

Mr. Shoolbred. upon by Mr. Allard was £350 as against £240 for the Gramme. The machines at Macquarie and at Tino, though of precisely the same size as Mr. Allard's, had not diminished in price, but had been increased to about £400; a good continuous dynamo of the modern type would probably cost but little more than one-quarter of this sum. In those exceptional cases where a moderate expenditure was contemplated, it was surely worth while to consider the question, whether a continuous-current machine might not be made use of, especially as the makers of those machines had denied that the disadvantages as regarded reliability, alleged against them, really existed; at any rate to the extent experienced in former days. He might mention a case of his own, to show that continuous-current machines might be depended upon. It was a case in which it was of extreme importance that the light should be kept constantly going. The machine was a small one, and no special precautions were taken; yet the light was given for nearly nine hundred hours without the slightest stoppage. Any failure would have been of great disadvantage, and would possibly have been attended with loss of life. As to the fluted carbons shown by Sir James Douglass, he should be glad to know whether they would not also tend to diminish the crater, or the flattened end produced upon the positive carbons by the continuous-current; thereby rendering the depression of the curve less accentuated than at present. The Author's arrangement, by which the light was diminished upon the near horizon, and projected seawards in greater abundance, appeared to be of very great value. As to the use of electric light on board of the light-ship outside of Liverpool bar, mentioned by Mr. Crompton, grave doubts had been expressed on the score of electric light blinding those navigating in passing ships. If what the Author had said could be done, namely, the light could be thrown into the distance, and not allowed to come on the near sea, or in contact with the ships passing near, it would no doubt be a great advantage. To illustrate this, there existed in Liverpool about two dozen electric mast-lights, which Mr. Lister had placed at the Canada Dock entrance, and in the immediate vicinity; as also at the Herculaneum Dock. They were 80 feet above sea-level; but complaints had been made even of them by persons on the river. How much more serious would the complaints be, where the light was not much more than 20 feet above water-level?

Mr. Dowson. Mr. J. E. Dowson said there was very little difficulty in preventing the escape of gas in his gas-making apparatus. The gas would come from the gas-holder below, and, whether the

pipe was carried up inside the lighthouse or outside, it would come quite safely to the engine, from which there was an exhaust pipe. He therefore failed to see how there could be any escape of gas in the building. He had seen many gas-engines at work, and had never met with any trouble of that kind, the gas being always enclosed in the pipe, in the engine, or in the exhaust. He agreed with the Author that, in many cases, gas-engines were suitable for lighthouse purposes, but it was right to face the fact that in certain cases they would not be suitable, and this remark applied not only to gas-engines but to other motors. Where a lighthouse was easy of access, and where the attendants had sufficient mechanical skill and experience to keep the dynamo and engine in perfect order, no doubt an electrical installation would be the right thing, and for such purpose a gas-engine would be a very suitable motor. If, however, the lighthouse were difficult of access, or if the attendants could not be relied on to keep the plant in thorough order, the risk of an electric installation would, he thought, be too great to run. Whether the motor were a steam-engine, a gas-engine, or a hot-air engine, it or the dynamo might go wrong if not properly looked after. The fuel-consumption of an engine driven with gas, made in such an apparatus as he had himself been working at, was no doubt very considerable. Formerly it was necessary to use anthracite for making the gas, but he had now succeeded in making it with ordinary gas-coke, which might be obtained in any town at a moderate cost, whereas anthracite was limited to certain districts. A recent careful trial, with an engine indicating 32 HP., had shown that the total consumption of coke was something under $1\frac{1}{2}$ lb. per I.HP. per hour, allowing for all sources of waste. For lighthouse purposes there would therefore be not only a great saving in the fuel consumed, but there would be a further gain in places where the transport or storage of fuel presented difficulties. Mr. Dowson.

Mr. Charles Ingrey desired to say a few words with regard to the motors used at Macquarie and at Tino, as to which he thought additional information might be given with advantage. He had been particularly interested by the observations of the Author as to the relative merits of the caloric-engine and the gas-engine. He could speak with some little authority on the point, because he had employed both engines at various lighthouses. The Author had condemned the caloric-engine, and had laid stress upon the fact that it was not economical. It would, he thought, be advantageous to know the quality of the gas employed at Macquarie, and also the amount consumed per effective HP., which would perhaps Mr. Ingrey.

Mr. Ingrey. afford the basis of a better estimate as to whether the gas-engine was as economical as had been supposed. Of course, efficiency in machinery in lighthouses was a matter of primary importance; but economy in all public works was also necessary. When gas was used as a luminary for a lighthouse, a gas-engine could, no doubt, be employed with great advantage for many purposes, such as for fog-signalling or for hoisting; but it was a question whether it would be economical to construct special gas-works to produce the motive power. The Author had given two diagrams of the caloric-engine, and he had given 18 lbs. as the initial pressure. He would ask the Author whether that was the maximum pressure obtainable? He had seen engines of the same dimensions, having 24-inch pumps, 32-inch cylinders, and 22-inch stroke, with a pressure of 30 and 36 lbs. on the gauge, giving 14 effective HP., with a consumption of coke less than 2½ lbs. Sir James Douglass had stated the result of his experience as to consumption of fuel per HP. per hour as 3 lbs. As far as Mr. Ingrey's experience went with engines of this kind, he thought that the statement given by the Author, that of 33 indicated HP., 17·7 and 6·3 were absorbed respectively by the pump and by friction, was apt to be misleading. The air-pump of a caloric-engine should be taken as part and parcel of the engine itself; it was absolutely necessary to the engine, and the indicated power should be spoken of as the balance of the two diagrams. Friction in the caloric-engine was undoubtedly greater than in any other engine, by reason of the greater weights, the larger surfaces, and the heated parts; but the Author had assigned as his chief reasons for objection, first, that it took up a great deal of room, and secondly, that it was not economical in fuel. As to the space occupied, the Author, perhaps, had not considered the amount of room which would be occupied by the water-tanks, that were always essential for a gas-engine, nor the area required for the retorts, purifiers, and gas-holders, which were necessary for gas-works. As to the economy of fuel, he believed it might be taken that a gas-engine would consume 25 cubic feet of gas per actual HP. The cost of gas at Macquarie was not mentioned in the Paper. He believed, however, that at various lighthouses the cost, taking everything into consideration, was as high as 15*s.* or even 18*s.* per 1,000 cubic feet. He proposed to take one half of that, and say 8*s.* per thousand. With 4 lbs. of fuel (which the Author had stated to be the result of his experience with caloric-engines at Macquarie), with a gas-engine giving 9 effective HP., at 25 cubic feet per HP., that would amount to 225 cubic feet,

which at 8s. per thousand was 1s. 9½d.; whilst with 4 lbs. of coke 9 effective HP. gave 36 lbs. pressure, and taking coke at the high price of 30s. per ton, that would amount to 5¼d. Seeing that the light had to be exhibited every night in the year, the cost of working in the one case would be £328, and in the other £84—a consideration which would, no doubt, weigh a great deal with those who were responsible for the funds required to supply electric light in lighthouses. The mechanical work done, as approximately stated by the Author on p. 249, was 6·9 HP. or 7 HP., but on p. 259, referring to the 8 HP. gas-engine, he stated that 10 HP. was obtainable on the brake. He should be glad to learn whether that was the result of a personal test by the Author, because with the five 8-HP. gas-engines that he had recently erected at a lighthouse station, he tried each of the engines with a brake, and he was unable to accomplish anything approaching that effective result. Of course the great value of the gas-engine was now so well established, that anything he might say would not detract from its merits. It could be well and usefully applied in many positions where gas was to be obtained at a cheap rate, and where water was also procurable. He spoke of the caloric-engine as an old friend, because he had seen it working in many isolated holes and corners, far away from any skilled practitioner, and doing its work well. It had no pretence to beauty or elegance of form, and it certainly occupied greater space than engines of another character; but it had this one advantage, and that appeared to him to render it particularly applicable to lighthouse purposes. It was a total abstainer. Unlike the steam-engine, or the gas-engine, it did not require any water. He should like to ask the Author the following questions: What was the nature of the gas employed at Macquarie, the consumption per effective HP.; the first cost of the gas-making plant, and of the gas-engine; the amount of labour required to make the gas; whether the manufacture and storage of gas was attended with danger; what was the first cost of the caloric engine referred to at Tino; what was the cost per ton of fuel; and what was the amount of labour requisite to work it? Mr. Ingrey.

Mr. J. I. THORNYCROFT said that the Paper had given him great pleasure, in consequence of the care with which everything had been worked out in connection with the lighthouses described. He hoped that what he had to say would not be regarded as any criticism on the work, but he looked at the matter in a different point of view from that taken by most of the speakers. He referred particularly to the number of beams of light. He wished to know whether the lighthouse in question was an exception in its number of Mr. Thornycroft.

Mr. Thornycroft.

beams, or the number of rays from the centre. The lantern revolved about its axis in sixteen minutes. It was considered important, as pointed out by a previous speaker, that two lighthouses should not appear with flashes of the same period. From a stationary object, the speed of the rays travelling on the sea was of no consequence; but on board a vessel going at a rapid speed, at a considerable distance from a lighthouse, the period of flash was affected by the speed of the vessel. Taking a radius of about a mile, the speed of the beam was only about 23 miles an hour, so that a vessel might at that speed sail round the lighthouse at a mile radius and it would see no lighthouse at all, or it would see a continuous light when sailing in the same direction as the beam, and it must be remembered that in the speed of the vessel so considered, the speed of the tide was included. When sailing in the opposite direction, or meeting the beams of light, the period was lessened, and under the above conditions reduced to one-half. That consideration, however, led him to the proposal of Sir William Thomson, who held that lighthouses were not sufficiently distinguished by their periods. If flashes could be made distinct, independently of their absolute time-value, it did not matter whether the time was accelerated or not. There were, no doubt, optical reasons which made it more convenient to divide the light into a great number of beams, and of course there was an economy in not turning the light round too often. He did not know whether, in the case in question, the lighthouse-keeper had to wind up the clock which turned the lantern, if so, he would no doubt be gratified by its slow motion, because that would mean less work. But in the case of an electric installation, the work might be done at a more rapid rate, by power taken from the engine. With regard to the large optical apparatus used, he thought the Author was perfectly right, because electric light was not such a small point as many persons seemed to think. Some imagined it to be a point between two carbons; but taking a continuous-current light, the crater of the positive carbon was of considerable size. The limit, to which the image of the carbon really could be thrown on the distant horizon, depended on the distance of the lens from the carbon. In other words, the image of the carbon on the distant horizon was as much larger than the absolute carbon, as the distance from the lens to the horizon was larger than the distance from the lens to the carbon. Taking 2½ feet, which was roughly about the distance, there was a large ratio, and the smallest image, which a perfect lens would give, was limited by those conditions. In fact, a light-

house might be considered a sort of camera turned inside out. He had arranged what would be found a convenient expression, for calculating the period of a light as observed from a moving vessel, in which the observed time T_1 from flash to flash of any revolving light with beams at equal intervals was given by the expression— Mr. Thornycroft.

$$T_1 = \frac{T}{\dfrac{1 \pm V n T}{2 \pi r}}$$

in which T was the interval of flashing seen from a fixed point, V the velocity of the vessel at right-angles to the radius r, π the distance from the light, the + or − sign being used when the vessel's motion was contrary to or in the same way as the beam of light, and n the number of beams proceeding from the light.

Mr. E. A. Cowper said that the Author had stated, p. 252, "In future lighthouses, when a steam-engine cannot be employed, it would be preferable on every ground to use gas-engines." Mr. Cowper did not know a situation where a steam-engine could not be employed. It was easy to make a dry condenser in which no water in contact was needed for the purpose of condensing steam; something like the dry condensers carried by some tramway locomotives. In that way every drop of water was returned to the boiler. At all lighthouses there surely must be water enough available to put into the boiler; and if it was condensed and continually returned, there would be no difficulty in working the steam-engine, and it would need far less water than a gas-engine. On a hot day in summer there might be 26 inches vacuum. He therefore thought that a steam-engine of simple character was a safer thing to depend upon than a hot-air engine. The hot-air engines he had seen did not satisfy him, either as to certainty of working, or regularity of speed. He did not say that hot-air engines always turned out badly. He had known Captain Ericsson work them better forty years ago; but he nevertheless thought that a plain, straightforward steam-engine, condensing with a dry condenser, was the best thing to trust to. There was no difficulty in making a simple and compact boiler for the purpose, and it was, as far as his experience went, less trouble to attend to it than to the gas-producer. He did not know how far the Dowson gas-producers had overcome the difficulties of previous ones; but he believed they were better than most of the old ones, which were troublesome to work. There should certainly be a gas-holder, so as to give a continuous and uniform supply of gas, thus getting a uniform power in the engine. But a gas-holder in a lighthouse Mr. Cowper.

Mr. Cowper. was not always advisable. If room could be found, it should have a house built over it, in order to prevent the wind from blowing it away, and many other little arrangements should be made. Although a gas-engine was more uniform in its motion than a hot-air engine, he thought that a steam-engine would beat them both. A gas-engine required a supply of water to keep it cool, whereas a condensing-engine with a dry condenser did not.

Captain Sir George Nares. Captain Sir GEORGE NARES, R.N., K.C.B., wished to say a few words, from a seaman's point of view, on the question as to when and where to use electricity in lighthouses. Sir James Douglass had already touched on the same subject, but the discussion had generally taken another direction. Any one studying the South Foreland experiments, would be strongly impressed with the great room there was for the improvement and the cheapening of electric light, as competing against gas and oil. He wished particularly to know what intensity of electric light the Author was alluding to? A description had been given of the very powerful lights at Macquarie and at Tino, lights of 6,000,000 or 7,000,000 candle-power. The Allard system of a cordon of electric lights round the French coast, established a few years ago, was based upon an intensity of only about 500,000 candle-power. He wanted to bring the question down to a seaman's point of view; which was one of intensity rather than one of the special illuminant employed. All that seamen wanted was intensity exactly in the degree in which it would be useful to them. At present there were in use flame lights of the same intensity as that provided by electricity in the Allard system; and as the flame was cheaper, shipowners, who would have to pay for the lights, would naturally prefer oil or gas to electricity. The maximum light required at sea in fine weather was far less than the 500,000 candle-power that could be obtained cheaply with gas and oil; so much so that lighthouse engineers only provided about 100,000 candle-power for use in ordinary states of the atmosphere; all excess of light above this was in reserve for use during fog. He agreed with the Author that it was rather a dangerous matter to put in the hands of a lighthouse keeper, who could not tell how far the fog was extending, the power of directing the whole of the light to the near horizon. When it was a question of dipping the light of 6,000,000 candle-power, all that was wanted was a light of about 250,000 candle-power directed to the sea horizon: that would penetrate as far as the rotundity of the earth allowed; more light was not wanted; all the rest was reserve, that might be wanted in a fog. Sir James Douglass in the St. Catherine light, and Messrs. Stevenson at May Island, had arranged that

very well; they had arranged that the reserve light should come down to the near horizon when it was wanted in a fog, leaving a certain beam directed out to the distant horizon in case the fog was less dense in the distance. The Author's arrangement in grouping lights that required special treatment was a good one. As a rock station, where the deep water near the shore gave little or no indication to a vessel being near danger, May Island was a good example, and here the Commissioners of Northern Lights had provided an electric light of extreme power. As a seaman he thought there was a limit to the power that was wanted in a long-shore range of lights, even in a fog. Supposing 500,000 candle-power could penetrate a fog 1 mile or 2 miles, 6,000,000 or 7,000,000 candle-power electric light would not go more than 100 yards or so farther. Were seamen to be induced to depend upon a coast light being visible in a thick fog, and to run for it at all hazards? If so, it would be necessary to have lighthouses so that the range would interlock at 2 or 3 miles distance. Captain Sir George Nares.

Dr. HOPKINSON, in reply, said that Sir James Douglass had alluded to the dipping of the light in foggy weather in shore. The fact was that the difference between Sir James Douglass and himself was not a very great one. Dr. Hopkinson had put forward a view that there were cases in which it was evidently expedient to dip the light. On the other hand, he thought that there were cases in which it was not expedient to do so, and he had pointed out some of his reasons guiding the determination, which must always depend upon a consideration of the particular case. Sir James Douglass had emphasized somewhat the considerations which led to the dipping of the light, but he would hardly go so far as to say that there were not some cases in which it would be better to abstain from giving that power to the light-keeper. The difference between them therefore on that point was simply one of degree, and that a very small degree. The question which Sir James Douglass had asked had been already dealt with by Mr. Dowson. He had drawn attention to the fact that the Dowson gas, consisting as it did in a large measure of carbonic oxide, was poisonous gas, which, if it escaped, would be destructive to life. There were other agents which, if allowed to escape, might be destructive to life, as, for instance, an explosion of ordinary gas. The only question was whether it could be so contrived, that in all human probability there should be no escape of gas, and he thought it would be generally agreed that it was within engineering resources to secure that the deleterious carbonic oxide should be confined to the pipes, to the gas-engine, and possibly to Dr. Hopkinson.

Dr. Hopkinson. the exhaust, as Mr. Dowson had pointed out. Professor Adams had touched upon one suggestion of interest, that in order to obtain, with the exceedingly small centre of light afforded by the electric arc, that necessary divergence ordinarily given by the magnitude of the flame, the arc should be placed somewhat out of focus, that the lens should be approximated somewhat towards the centre of light. No doubt if engineers were under the obligation to make use of precisely the same apparatus for electric light as for oil light, the suggestion would be a desirable one to adopt; but it was far better, in the case of electric light, to make the optical apparatus suit that light, and not to suit something else. Even although the apparatus were already in existence for which it was proposed to use the electric arc instead of the oil flame, it would be better economy to remove that apparatus and employ it in some other situation, and to design a special apparatus for the electric light. Professor Forbes had raised a number of points of interest. He had first dealt with the use of a reflector in lighthouses. At Macquarie a reflector had been found of the greatest advantage, in the way in which it was used, for it gave a source of light horizontally larger but vertically no larger, and consequently it diminished the difficulty of supplying the necessary horizontal divergence to the emergent beam. Professor Forbes had mentioned some cases in which the lighthouse appeared to give a sort of double flash. In the case of Macquarie such a thing had never been observed, and from his own observation he was confident that nothing of the kind could occur. Still, he did not doubt the accuracy of Professor Forbes' observation, which had perhaps been made upon ordinary oil lights. If a reflector was used with them, it would be dealt with in a different way from that in which it had been used at Macquarie. The image formed by the reflector would be superposed upon the flame itself, and consequently no splitting of the flash could result from its employment. Possibly the fact observed might have resulted from one of two causes—the lighthouse observed by Professor Forbes might have had a lantern with a polygonal glazing, in which case it sometimes occurred that false flashes were reflected from the glass. Or, again, it was possible under some circumstances to get two maxima in a flash, owing to the fact that when a large oil flame was used, and the outer rings only were burned, there was a greater intensity at the edge of the flame than in the middle, and undoubtedly the beam in that case was a little brighter at the beginning and at the end than in the middle; but he had never heard of any case in which that

Dr. Hopkinson.

had caused the slightest practical inconvenience, or any approach to mistake. With regard to the use of accumulators, his object in putting forward the proposal for a future lighthouse, was to give it as definite a shape as possible. He did not want to review all the possible ways of accomplishing this, but to give it some definite shape, which would be capable of being criticised. In doing that, he had come to the conclusion that, on the whole, at the present time the plan he had proposed would cost somewhat less, would be more convenient, and, on the whole, more economical of power than the use of accumulators. At the same time he did not wish to be dogmatic. He did not doubt that a very satisfactory and economical arrangement might be made with accumulators, but so far he preferred the arrangement proposed in the Paper. Mr. Crompton had considered the relative advantages of continuous and of alternate currents. As to the optical apparatus, there was no more difficulty in dealing with one than in dealing with the other, but they must be dealt with differently. It was not right to put an alternating-current arc into an apparatus which had been intended for a continuous-current or *vice versâ*. They required different optical treatment, and it was necessary for any one who had to design an optical apparatus to know with which source of light he had to deal. Mr. Crompton had also referred to the question of the introduction of electric light into light-vessels. Dr. Hopkinson did not see that there should be any serious difficulty in getting a satisfactory arrangement of electric light in light-vessels. He quite agreed that, so far as the machinery itself was concerned, there should be no difficulty; and though he thought that the optical apparatus would require very careful consideration in order to make the most of the electrical arc, and get a really satisfactory result from it, and avoid all objectionable effects, he did not believe that those optical difficulties would involve anything insuperable. Mr. Crompton had further alluded to the plan of rotating the optical apparatus by the power of the engine. At present, at all events, Dr. Hopkinson preferred to adhere to the ordinary clock-work, which might be made exceedingly accurate and very simple, for this reason, that up to the present time it had been always necessary to reassure lighthouse authorities in the use of electric light, by providing them with oil-lamps in case of a total break-down of the electric machinery. He did not say it was really indispensable, yet it was necessary to provide them in order to give that confidence which was desirable. If that were so, the rotating arrangement must be independent of the motive power

Dr. Hopkinson. which drove the dynamo machine. That might in time become a thing of the past, and lighthouse authorities might then with confidence drive the apparatus as Mr. Crompton was now doing. With regard to the figures given in the Paper as to the intensity of light that should be obtained by a current of 20 amperes, he had no doubt that the values assigned by Mr. Crompton were a good deal nearer than the figures which he had himself given in the Paper; but he was particularly anxious not to overstate the case. He wanted to be quite sure that no one would controvert the numerical basis upon which he had proceeded. He had, therefore, taken a figure which no one would venture to contradict. If Mr. Crompton's figures were correct, so much the better for electric light. Mr. Kapp had dealt with the question of coupling alternate-current machines parallel without mechanical connection. In the arrangement at Tino two machines were driven from one counter-shaft. In the first instance, when it was attempted to drive the machines together, there was a difference in the size of the pulleys of about 1 millimetre in 300 millimetres. Notwithstanding that, they synchronized perfectly, and the effect was sufficient to control the natural difference in the time of rotation of the machines. He was not prepared off-hand to say how far it was possible to go in that direction. The question had been fully dealt with in the lecture which he delivered before the Institution, and also in the Paper before the Telegraph Engineers. As to the question of the adjustment of the lamp in the apparatus, Mr. Kapp had referred to Fig. 18. The fact was that in all cases means were provided for horizontal as well as for vertical adjustment, and also for ascertaining that the horizontal as well as the vertical adjustment was correct. He thought that Mr. Kapp rather over-stated the case against the De Meritens machine. That machine was a fairly efficient one, though it did not come up to the best results obtained with a continuous-current machine. The objections to it were, the space that it occupied, and its high prime cost; and he might also add that the alternate-current arc was a less efficient converter of electric power into light than the continuous-current arc; still he did not know that the difference was such as to countervail the advantages that existed in the use of magneto-alternate machines in some cases. Mr. Shoolbred had alluded to the experiments carried out by Mr. Allard. Those experiments were made some time ago, and since that time the improvement in the continuous-current machines had been enormous; but the alternate-current magneto machine was much the same as it was when those experiments were tried. If the ex-

Dr. Hopkinson.

periments were repeated with a modern-continuous current machine, its economical advantage would be greater than that found by Mr. Allard. He entirely agreed with what Mr. Dowson had said, as to the limitation of the employment of gas-engines in lighthouses. He was not prepared to go so far as to recommend their use in out-of-the-way stations, where it might be a considerable time before the means of repairing them could be obtained. In such cases, and where the labour available was possibly black native labour, he should prefer the simplest burner that he could obtain. In giving the statistics of the hot-air engine and the gas-engine, he had confined himself to his own observations. With regard to the hot-air engine, it had never occurred to him to emphatically call attention to the fact that 17 HP. required in the compressor was necessary to obtain power; it seemed to him to be perfectly obvious. The efficiency in the use of gas was so well known, that it appeared to him hardly necessary to go into the question. His own experience of gas-engines, especially of the larger ones, confirmed pretty closely what the makers had claimed for them. Mr. Thornycroft had criticised the slow revolution of the apparatus at Macquarie, and mentioned the case of a vessel steaming at high speed at a mile distant from the shore. Of course seamen could be expected to pick up the light at a considerably greater distance than 1 mile or 2 miles, and they would know precisely of what character it was. It could of course be understood that Mr. Thornycroft would lay great emphasis on the high speed of a vessel, because no one had succeeded as he had, by scientific methods, in obtaining a high speed not only for large vessels, which was a comparatively easy problem, but for the smallest. Mr. Thornycroft had also alluded to what Sir William Thomson had urged years ago, that better distinctions should be given to lighthouses. This was in 1872, at a meeting of the British Association at Brighton,[1] and Sir William Thomson's suggestions had certainly not been neglected. In 1874 Dr. Hopkinson proposed a particular form of apparatus to produce a grouping of the flashes. Since that time Messrs. Chance Brothers and Company had made over a dozen ocean lights on that system. Group-flashing lights had also been introduced by the Trinity House for light-vessels; and not only so, but eclipsing lights for giving distinctions had been introduced all round the English coast, and in China, India, and Australia. So that, considering the short

[1] Transactions of the Sections, p. 251.

Dr. Hopkinson. time that had elapsed, he thought lighthouse engineers had not allowed the grass to grow under their feet. Mr. Thornycroft fully appreciated the use of a large apparatus, and the advantages resulting from it. Lighthouse engineers would thank Mr. Cowper for directing attention to another resource when water was scarce; but he doubted whether a steam-engine such as Mr. Cowper had suggested would be the most convenient thing when small power was required, such as $1\frac{1}{2}$ HP. In such a case he thought a gas-engine would be better. Sir George Nares had clearly stated the problem to be solved in dealing with electric light, and it was that problem which he had endeavoured to solve. Sir George Nares had pointed out, that though a great power was desirable, there were limits to the extent to which it could be usefully employed, and the great question was how to supply the light cheaply when small powers were required. It was proved beyond doubt that with electric light any power could be given that could be usefully employed, and in the apparatus which he had proposed he thought that the maximum power that would be useful was provided. On the other hand, it was desirable to obtain the production of ordinary power with economy, and he saw no way of obtaining it, except by concentrating the apparatus in such a way, that the gas-engine dynamo machine and lamp should constitute a gas-burner, which could be handled by one man. There were many points on which he had not attempted to give a positive opinion, but there was one point on which he had given a rather positive opinion—an opinion that had been held by others for some time—namely, that it was desirable to employ a large apparatus for electric light. The fact was that there was a difference of opinion in the matter. British engineers had long been in favour of the larger apparatus; French engineers had been in favour of the small apparatus; but he ventured to say that the English engineers would be proved to be right, and French engineers would come round to their opinion. Messrs. Crossley had kindly exhibited their 1-HP. gas-engine, and the Edison and Swan Company had lent a small dynamo machine, manufactured by Messrs. Mather and Platt, from which it would be seen that the space occupied was very small; and there was no reason why the machinery should not be placed immediately beneath the lantern.

Correspondence.

Messrs. BARBIER and FENESTRE stated that their views were in complete accordance with those of English engineers as to the dimensions that should be given to the apparatus of electrical lighthouses. Like them they preferred apparatus of the largest diameter, such as had been adopted at Macquarie and at Tino. With apparatus of this size, it was possible to distribute the light over the surface of the sea to be illuminated, with great precision, and to draw therefrom the best effect. The Author recognized the advantage, for certain isolated lighthouses over reefs, of which it was important to warn mariners, of being able to dip the beam over the near sea during fog; but he did not think this advisable for large lights placed on coasts of wide extent. Not only, however, according to them, were dipping lights useful in the first instance, but also in a general sense. At all events it could not be denied they would be so, wherever it was judged useful to have a siren near the lighthouse. As to the objection, that it would be dangerous to leave to the keeper the responsibility of estimating whether or not it was advisable to dip the luminous beam, it was not so serious as some engineers considered; because a considerable portion of the luminous rays would be continued in their normal direction, and, in case of mistake on the part of the keeper, the light would never be extinguished, and in fact because this error was hardly possible. Now, what was required of the keeper in the present circumstance? It was not great intelligence, but good sight only, such as sailors and light-keepers generally possessed. The experiments at the South Foreland had shown that electric lighthouses, while more powerful, were at the same time more costly than those lighted by oil or by gas. The Author proposed to diminish the prime cost of electric light by substituting motors worked with Dowson gas for steam-engines, gas-engines, or hot-air engines. They did not deny the economy that might be obtained by this means, but they did not believe it would be sufficient to ensure the development of electric lighthouses. The chief objection to electric light was not only its high prime cost in lighthouses, but more particularly its method of production which involved a comprehensive and complicated machinery, and therefore also a more numerous staff, and more difficult to recruit. If the arrangement suggested by the Author constituted progress in this respect, they thought it was not sufficient; for there would be the

Messrs. Barbier and Fenestre.

Messrs. Barbier and Fenestre. ordinary machinery, less important indeed but with as many parts, as an apparatus for making gas. There were, in addition, electric conductors, gas-pipes, and water-pipes for cooling the cylinders of the gas-motor, all of which seemed to them too complicated. They thought that, under present circumstances, it would be well to employ more powerful dioptric refractors than those now in use, say hyper-radiant apparatus 2·66 metres in diameter, with mineral oil as the illuminant. It would be as well not to lose sight of the fact that the illumination of lighthouses by mineral oil possessed great advantages over their illumination by electricity. With respect to the supplies, mineral oil, which was generally employed in lighthouses, could be had cheap everywhere at the present day. And, as to the service, could anything be more simple than the management of a lamp, without mechanism very often, which burned during a whole night without its being necessary to touch it? Evidently not; and if five keepers were ordinarily considered necessary for the service of an electric lighthouse, two would be always sufficient for a lighthouse where the illumination was effected without any mechanism. As to the power of the hyper-radiant apparatus, it had been shown by the trials at the South Foreland in October 1885, made by Mr. Harold Dixon, of a lens that had been ordered from them by Messrs. D. and T. Stevenson, MM. Inst. C.E. These trials had proved that the lighting power of hyper-radiant lenses of 1·33 metre of focal length was more than double that of lenses of 0·92 metre.

Thus, without spending a penny more on the illuminant, and in the expense of service, the available light could be more than doubled. Lighthouse apparatus so constituted, with lenses of long focus, was evidently economical, and for lighthouses for extensive land-fall they considered them to be practically the best.

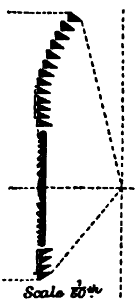
Mr. Boulvin. Mr. J. Boulvin observed, with respect to the Brown hot-air engine, that it had been brought into use for light-vessels off the Flemish coast. The engines resembled the one adopted by the Corporation of Trinity House at Seven Stones, the cylinder being 24 inches in diameter and lighter than at Tino. The indicator diagrams closely resembled those given by the Author on p. 253 of the Paper. The pressure and performance were similar, and the number of revolutions per minute was from 60 to 64. From measurements that he had made of the work employed in compressing air in the reservoir of the sirens, he had found that the net HP. was 6·5, with a consumption of fuel of 1·18 kilogram per

HP., and per hour 2·6 lbs. This was a better result than had been obtained at Tino, where the consumption had been 4 lbs.; but the figure to which he made allusion, 2·6 lbs., had been obtained by subtracting the ashes, and did not include the combustible for the kindling. For light-vessels, and generally for sound-giving signals where the machines worked discontinuously, the hot-air engine seemed to him admirably adapted. It had not caused the least inconvenience in the four years that it had been in use. Whilst a steam-engine, fed with sea-water, would have probably already corroded a boiler in the interval. As to the economy, he believed that no motor of like small power could be compared with it, whether of steam or of gas. Admitting the consumption of coke used at Tino, which was 4 lbs., he thought it would not be far from the truth to estimate that of a small steam-engine at one-and-a-half time that amount. There were probably hot-air machines equally good as the Brown motor. The reason why it had been preferred in Belgium was, that its first cost was less than that of other machines at that time in the market, that all its parts were accessible, and that the cylinder and the pump were vertical and balanced. Once having selected this type, he had naturally adopted it for the other stations; it was always desirable to have uniformity as much as possible. The only inconvenience of the old Brown motor was, that it was necessary to use sperm oil as the lubricator for the leathern fittings of the piston, but now the pistons were entirely metallic, and could be greased with ordinary oil. The fact that the motor was single-acting was certainly inconvenient, in respect to the uniformity of motion; the variation of speed, which was plainly manifest in the sound of the siren, was perhaps of more serious inconvenience in the case of electric light, for which the only remedy was coupling two machines with cranks opposite. Still, the regularity would be less than with two double-acting machines, coupled with cranks at right-angles; but the majority of gas-engines were in the same condition, and the Otto motor, for example, one of the most expensive, was even more disadvantageous, since it only gave one stroke in two revolutions. Mr. Boulvin.

Mr. ALAN BREBNER, jun., wished to rectify somewhat the reference made by the Author to the double-condensing apparatus proposed by him. It differed from the form of apparatus used for Macquarie in origin and in purpose. It was obtained by starting from the ordinary fixed-light apparatus, and modifying it so as to cause horizontal, as well as vertical, condensation. The Macquarie apparatus, the refracting portion of which was of a form originally Mr. Brebner.

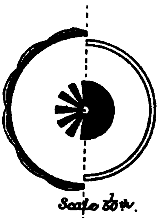
Mr. Brebner. proposed by Mr. Thomas Stevenson, M. Inst. C.E., was obtained by starting from the revolving-light apparatus and modifying it so as to diminish the amount of horizontal condensation—a result necessitated by the smallness of the electric arc. The Author had not furnished an account of the mode of adjusting the catadioptric prisms of the Macquarie apparatus. He knew of three different methods of obtaining approximately the horizontal and the vertical divergencies required; but he would only ask the Author to describe in detail the method he had actually used. In his Paper[1] on single-agency double-condensing apparatus, he had indeed given a design for an apparatus condensing each 15° in azimuth into 3°, and he now admitted that the best form of apparatus for this purpose was the Stevenson-Hopkinson modification of the revolving-light apparatus. He then had specially in view the object to obtain the "intermittent" characteristic, and he had recommended an apparatus in ten compartments condensing 36° into 24°. A comparison between his own and the Macquarie type of apparatus showed that strictly the two were not comparable, but that each had its own appropriate place within determinate limits, where it would be found better than any substitute, but outside of which its defects assumed such proportions as would preclude its adoption. For his part, he should not propose the apparatus described by him as a substitute for that of Macquarie, and he thought he might assume that the Author would not suggest the latter system for condensing 36° into 24°. Thus his apparatus could be compared only with the combination of fixed-light apparatus and vertical prisms, suited to produce the same effect. He had recently designed in detail, and determined what was novel in the constructional arrangements of the apparatus of two lights of the third order, one of which was now in operation at Hakodato, Japan, and the other, the rough design of which was due to Messrs. Stevenson, at Ailsa Craig. Fig. 13 represented in black the lateral section of a panel of the apparatus, the additional outline showing the maximum, or axial, increase of a section of glass. Fig. 14 showed in horizontal focal

Fig. 13.



Scale 1/20th.

Fig. 14.



Scale 1/20th.

[1] Minutes of Proceedings Inst. C.E. vol. lxx. p. 386.

section (the black portion being the section at a horizontal joint of the refractor) the Ailsa Craig arrangement, in which one-half the circumference was occupied by a dioptric mirror, the characteristic being a sextuple flashing light. The artificial divergence of each 30° compartment was 10°, which would be increased to about 15° by the gas-flame surrounding the focus, so that each eclipse and flash within a group was of equal duration. The lengthened eclipse separating one group of flashes from another took place when the mirror, which revolved with the apparatus, passed between an observer and the lamp. The Hakodato apparatus had at first been designed in ten compartments of 36° condensing into 12°, but it was afterwards changed to one of twelve compartments of 30° condensing into 10° similar to those of the Ailsa Craig apparatus. Its characteristic was "intermittent," and the light on the landward side of it was returned through the flame by a fixed dioptric mirror. With regard to the Ailsa Craig apparatus, it was satisfactory to find that the captains of steamers which frequented the Clyde were unanimous in pronouncing it the best light on the river. He was not sure whether the Author would have preferred to use apparatus of the Macquarie type for Hakodato and Ailsa Craig, and not knowing the Author's method of adjusting the catadioptric prisms, he lacked the data necessary for a complete comparison. He had, however, compared them, as made, with the combination of fixed-light apparatus and vertical prisms calculated to produce the same effect, and had found that the single-agency arrangement transmitted in the catadioptric portion 4 per cent. more than the double agents, and 8 per cent. more in the refracting portion. He believed the Macquarie form of refractor might have been used with as good results optically, but was unable to see how it could be made at a cost appreciably less. The catadioptric portion could not have been constructed as for Macquarie, without materially reducing the optical accuracy. Comparing the cost of the Hakodato apparatus with that of the fixed-light apparatus and vertical prisms, to produce the same effect, that of the former was 13 per cent. higher. This, however, arose from the fact that the former was of novel shape, whilst the latter was a current form of construction, the cost of which had been brought down by competition of long date. Hence intrinsically such apparatus kept within proper bounds was the best both as to cost and as to optical efficiency. The mode of construction and of testing, moreover, allowed of obtaining very accurate work, and the apparatus was well suited for electric intermittent lights. Mr. Brebner.

Having said so much respecting the form of apparatus proposed

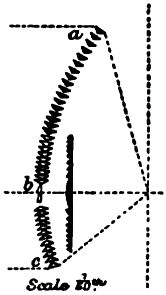
Mr. Brebner. by him, he would express the opinion, that the value of the Stevenson-Hopkinson modification of the dioptric revolving-light apparatus could hardly be over-estimated, as a means of maintaining the revolving-light characteristic by single agency when the luminary was electric, and that it might be usefully employed for prolonging the flash when the luminary was a well-condensed oil or gas flame. The power of the Macquarie light might easily have been increased, by condensing 30° instead of $22\frac{1}{2}$° into 3° for the refracting portion; whilst a diminution of divergence, from the catadioptric prisms, would have been compensated by additional brilliancy given to the core of the flash.

The only other question, to which he would refer, was that of the desirability of dipping the strongest light of a lighthouse during fog. The subject was a grave one, but the Author was not too soon in bringing it into the arena of discussion. He would first notice a passage from the pen of Mr. Thomas Stevenson, which those who had seriously considered the problem must recognize to be of great weight. Mr. Stevenson said, "It always appeared to me that, had we an easy way of doing so, we ought to increase temporarily the dip of the light, and thus, during haze and fogs, to direct the strongest beam to a point much nearer the shore than the sea horizon. At present we direct our strongest light, not only in clear weather, when it can be seen, but also during fogs, when it cannot possibly be seen, to a part of the sea where the danger to shipping is in most situations the smallest; and this is done to the detriment of that region, where, even when the weather is hazy, there is at least some chance of the light being visible, and to a part of the sea where the danger to shipping is unquestionably the greatest."[1] To Mr. Stevenson was due, not only the original idea of temporarily dipping the light, but also the first practical application of that idea, which was comprised in the recently installed electric apparatus at the Isle of May. He did not consider the plan used at the Eddystone, of installing a second optical apparatus and lamp, and lighting the latter only in time of fog, as answering to Mr. Stevenson's idea, which did not imply a double set of apparatus. The method at the Eddystone not only involved the extra prime cost of the apparatus in duplicate, of the increased height of lantern and interest on the same; but it was objectionable in so far as it comprised a wasteful type of apparatus, in which from one-third to one-eighth of the light produced was constantly thrown away, and from which the Fresnel catadioptric prism,

[1] "Lighthouse Construction and Illumination," p. 237.

combining so admirably in its action, utility, economy and beauty, had been removed. With regard to the dense flint glass, by the use of which it had been sought to diminish the angles of light lost above and below the apparatus, stripped of the Fresnel reflectors, he had had occasion to see the comparatively miserable appearance of the light which found its way through them. The Isle of May apparatus, besides being the first practical application of the idea referred to above, was remarkable also in the fact of its introducing for the first time catadioptric prisms, improved in transmitting power by reduction of the size of the prisms and consequent absorption. This apparatus was, however, unquestionably faulty in the almost entire suppression of the dioptric drum. When the transmitting power of dioptric and catadioptric prisms, at gradually increasing angles above the focal plane, and for the usual dimensions of glasswork was determined, with the use of Mr. Allard's coefficients for absorption and surface reflection, the dioptric prism was found to transmit more of the incident light than the reflecting prism in the same position, up to more than 40° of inclination. The justification of the Isle of May apparatus was that, as a continuous-current electric machine was to be used, the best portion of the light would pass to the cupola at about 50° above the focal plane, where the catadioptric prism was indubitably more efficient than the dioptric; and as it was desired by lowering the carbons to lower the greater part of the whole light, it appeared impossible to obtain this result otherwise than by carrying the catadioptric prisms abnormally near to the focal plane, leaving only a small angle to be occupied by dioptric prisms, which should light the near sea when the others lit the horizon, and *vice versâ*. This apparatus was shown in vertical section at *a b c*, Fig. 15. After examining Mr. Stevenson's design for the Isle of May, another mode of temporarily dipping the light occurred to him, which he had described in a communication to the Institution.[1] This dealt with the conversion of fixed-light apparatus, whilst that of a revolving-light apparatus was shown in Figs. 16. These Figs. represented an octagonal revolving-light apparatus of the second order, now being made by Messrs. Barbier and Fenestre for the Government of Japan. The advantages of this method, over any other having the same purpose in view, might be thus summarized:— Mr. Brebner.

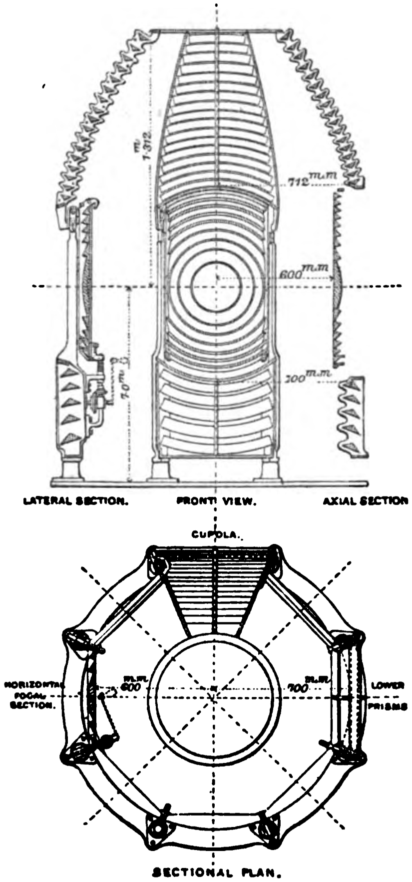
FIG. 15.



[1] Minutes of Proceedings Inst. C.E. vol. lxxviii. p. 361.

Mr. Brebner. 1. The dipping of the light was performed without any meddling with the lamp—a thing often inadmissible, and never desirable. 2. It allowed of maintaining both the refracting and the totally-reflecting prisms in those positions where each was superior to the other. 3. It allowed of the whole of the light traversing the refractor, and of that traversing the upper cupola, being dipped simultaneously. 4. It answered the objection of there being danger in entirely depriving the horizon of light, by reserving about one-tenth of the whole light, and directing it constantly to the horizon. 5. Several minor points. *a.* It included the improvement of reduction of the absorbing mass of the catadioptric prisms introduced in the Isle of May design. *b.* It allowed of the loss of light from obstruction by horizontal stays, inseparable from the ordinary forms of apparatus, being reduced to zero. *c.* The dipping or re-raising of the light was effected by mechanism of extreme simplicity.

Figs. 16.



Octagonal Revolving-Light Apparatus, Second Order, for clear weather and Haze-Brebner's System. Scale $\frac{1}{10}$ full size.

Before describing the apparatus, Figs. 16, it might be of interest to give some account of experimental trials made at the South Foreland in the summer of 1885, on a panel of the Isle of May apparatus of 700-millimetre focal distance, *a b c*, Fig. 15, and on a combination, shown in black, Fig. 15, of a portion of the cupola of the same, along with a movable dioptric drum of 500-millimetre focal distance, specially designed by him for these experiments. A panel of vertical prisms condensing 45° horizontal into 3° was placed in front of each arrangement. The Isle of May apparatus was made by Messrs. Chance

Brothers and Company, the movable drum and its settings, including chains and pulleys of the forms shown in his former Paper,[1] and leaden counterweights, were made by Messrs. Barbier and Fenestre. He was indebted to Messrs. Stevenson, for having sanctioned the comparative trials of the Isle of May dipping arrangement and his own. For a fair appreciation of their results, it was necessary to bear in mind that, there being scarcely room inside the Isle of May apparatus for a drum of 600-millimetre focal distance, which, as seen by Figs. 16, was the proper one for his second-order system, one of 500 millimetres was chosen, so that, on the completion of the experiments, it might be incorporated in a complete apparatus of the third order. For this reason, the portion due to the refractor of intensities registered for his system should be increased by one-fifth. Moreover, the upper reflectors used along with the movable drum had not, like those in the complete Isle of May panel, been adjusted for a height of focal plane of 240 feet, but had been roughly set for the level. Mr. Brebner.

The photometrical measurements were made by Mr. Harold B. Dixon, whose report Messrs. Stevenson had obligingly communicated to him. The following measurements were taken from it:—

July 16th, 1885. Slight Haze. French Lights Visible.

Time.	Burner.	Lens.	Illuminating Power in Pyres, or Thousands of Candles.
P.M.			
9.40	Single lens electric	Stevenson . .	1,150
10.0	Biform oil, 6-wick	Eddystone . .	66·5
10.10	Single lens electric	Brebner . .	1,220
10.30	Biform oil, 6-wick	Eddystone . .	77·6
10.40	Single lens, electric, 2 machines . .	Brebner . .	1,820
10.55	Biform oil, 6-wick	Eddystone . .	76·1
11.0	Single lens, electric, 2 machines . .	Stevenson . .	1,840
11.15	Biform oil, 6-wick	Eddystone . .	77·4
	July 17th.[2] Slight Haze.		
10.40	Single lens, electric, 2 machines . .	Brebner . .	1,380
10.55	„ gas, 108 jets	Mew Island .	39·2
11.10	„ electric, 2 machines . .	Stevenson . .	1,580
11.30	„ gas, 108 jets	Mew Island .	40·4
	July 18th. Very Clear.		
9.40	Single lens, electric	Stevenson . .	910
9.50	„ gas, 108 jets	Mew Island .	55·1
10.20	„ electric	Brebner . .	1,888
10.30	„ „ 2 machines . .	Brebner . .	3,190
10.45	„ gas, 108 jets	Mew Island .	54

[1] Minutes of Proceedings Inst. C.E. vol. lxxviii. p. 361.

[2] Measurements of the lenses with one electric machine on this evening omitted, because haze came on after the measurement of the one and before that of the other.

Mr. Brebner. When these three sets of experiments were compared, the difference between the measurements of the 16th and 17th and those of the 18th of July was remarkable, the latter measurements showing twice as much intensity for the Brebner arrangement, whilst the former showed an equal or greater intensity for the Stevenson one. He believed that the explanation of this anomaly was to be found in information communicated to him by Mr. James Sparling, the Resident Engineer at the South Foreland. Mr. Sparling informed him that on the 16th of July, when the two lenses were giving equal light, the carbons were not set properly relatively to the upper reflectors accompanying the movable drum; he had been obliged to leave the apparatus in charge of an assistant, who forgot his instructions and placed the carbons above the right position. The state of matters remained so on the 17th of July. On the 18th, when over 3,000,000 candles were registered, Mr. Sparling had personally set the carbons and attended to the light. Thus on the 16th and 17th the light from the upper reflectors of the Brebner panel must in great part have passed above the station of photometric measurements. This would plainly account for the above apparently contradictory results.

On the 18th of July Mr. Dixon had also measured, with the Nisbet photometer, the intensity of the beams dipped 5°, and found the ratio of intensity to be $\frac{\text{Stevenson system}}{\text{Brebner system}} = \frac{100}{130}$. Mr. Dixon said in his report to Mr. Stevenson, "for a horizontal beam the Isle of May lenses are of equal efficiency . . . . for the dipped beams the Brebner arrangement seemed decidedly most effective, the intensity of the Brebner beam being about one-third greater than the other." In this report, Mr. Dixon had not taken into account the information referred to above, supplied by Mr. Sparling. All the circumstances being considered, he thought the experiments left no doubt as to the superiority of the Brebner dipping arrangement, the chief reason for which was, that in the angles subtended by refracting prisms in it, and by catadioptric prisms in the other, the losses by surface reflection and absorption were 19 per cent. greater in the latter.

The upper cupola of the apparatus, shown in Figs. 16, contained the same profiles as those given in his former Paper,[1] except that in the new design there was but one supplementary prism instead of two, no greater depression of the refractor than 20 millimetres being required. The calculated weight of the refractor differed only by a few lbs. from that of the cupola, the two acting

[1] Minutes of Proceedings Inst. C.E. vol. lxxviii. p. 361.

as counterweights to each other, so as to reduce to a minimum the effort required for simultaneously lowering the former and raising the latter. When this was done, one of the lower prisms would have the light, incident on it from the lamp, intercepted by the bottom of the refractor; but at the same time the supplementary prism at the foot of the cupola would receive the light escaping above the lowered refractor, and it was calculated to direct this light to the horizon. Thus no loss of light resulted from the change of position of the cupola and drum; but a certain amount was gained, since the upper ray falling on the cupola was then at a higher angle. The specification described minutely the precautions to be taken in mounting the apparatus, which need not be dwelt on here; but it might be mentioned that the hooked form, given to the top of each alternate pair of vertical settings of the refractor, was intended to facilitate the mounting or dismounting of the refractor. Figs. 16 showed also a small guide-roller near the foot of the same settings, and running on the inner smoothly-polished face of the corresponding standard of cast-steel. Four such guide-rollers in bronze were destined to prevent lateral strains from acting on the double-threaded screw, which converted the manual effort spent in turning the removable handle, shown in dotted lines, into a vertical downward and upward movement of the refractor and cupola. A scale divided to millimetres and an index, one fixed near the screw, and the other moving with the drum, served to show the keeper where to stop the movement for a desired amount of dip. The lamp to be used being a three-wick oil lamp, it was unnecessary to give the apparatus a form differing from that of the ordinary revolving light. It could, however, be easily modified at any future time to suit an electric luminary, by readjusting the lower prisms, and placing inside each of the refracting panels a light plano-convex lens, suited to give the required horizontal divergence to the beam. Had the apparatus been intended for immediate use with an electric luminary, the refractor would have been formed similar to that used for Macquarie; and, in consideration of the meagreness of the trials made with dipping systems at the South Foreland, he would suggest that a complete apparatus, specially designed for an electric revolving light on his system should be installed somewhere, for a prolonged series of observations in all states of the weather. It would be an advantage to have beside it a powerful fog siren, in order to ascertain to what extent the use of the former might allow of the economy that would result from the suppression of the latter. Mr. Brebner.

Mr. Brebner. Instead of the distribution of light in the vertical plane, shown in his former design, and partially adopted in that of Figs. 16, there was another that might seem preferable to some persons, namely, that of lighting the near sea by one or two elements of the refracting drum, and sending all the rest of the light to the horizon in normal weather, so that, on moving the drum and cupola for dipping, the whole of the light traversing the former would go to the near sea up to 2 or 3 miles distance, whilst the cupola would spread the light from about 1 mile out near to the horizon, and so strengthen the light that was constantly thrown well out to sea by the fixed lower prisms.

The slight amount of freedom enjoyed by the movable cupola and drum would lessen the risk of breakage by earthquakes in countries like Japan.

The Author had admitted the utility of dipping the light of an isolated rock station; and he had adduced important arguments against it, in the case of a light commanding a long line of coast, and also for a low-lying light. There were, however, a few other points of at least equal importance, to which he had not referred. No doubt, when the whole amount of clear weather was compared with that of foggy weather, the importance of a light being visible to the limits of its geographical range was manifest. On the other hand, it should be remembered that loss of life or property was never caused by a light failing in this respect; while it frequently was by wreckage in the vicinity of harbours, to which ships in danger sought to gain entrance, or, again, by running ashore anywhere, for want of a warning signal. Further it was certain, that frequently the state of the atmosphere was such, as to render the intensest conceivable light incapable of penetrating beyond a few miles. Hence, in such cases, there was no need of apprehension at the thought of the light being directed over an area reduced four hundred times; it should afford satisfaction, inasmuch as thereby not only was a great and certain waste of energy done away with, but the likelihood of saving life, &c., was increased on the reduced area, infinitely more than four hundred times. It was not a question of choosing between making light visible at the horizon, or near the lighthouse; for the former was impossible, and it remained only to seek the attainment of the latter. A concrete example would illustrate the matter. In Mr. Dixon's measurements on the 19th of July, quoted above, an intensity of 3,190,000 candles was recorded for his apparatus with two machines. With a specially-designed apparatus, such as that of Figs. 16, modified to suit the electric arc, the intensity just named would be increased

to 4,500,000 candles. One-tenth of this, or 450,000 candles, would be constantly directed to the horizon during haze, and it was enough to carry farther than 15 nautical miles during 84 per cent. of the year, for conditions prevailing in the English Channel. From the same set of measurements, it would be seen that, in like atmospheric conditions, 108-jet gas-lamps in quadriform arrangement, with Mew Island lenses, would only give 220,000 candles. Thus the electric combination would continue, all through a fog, to direct to the horizon twice as much light as the Wigham quadriform, and there remained for dipping purposes more than 4,000,000 candle-light. Now, according to Mr. Allard,[1] in a fog such that this light would be visible to a distance of about 1 mile, it would require a light three thousand times more intense to be seen at 1½ mile, and no obtainable light would carry nearly to the horizon. This showed that in fog, the method of rendering a light visible, which consisted in diminishing its range, was far better than that of increasing its intensity, and that there was no exaggeration in saying, that, when the area over which the light was spread was diminished four hundred times, the chances of its being seen were increased very much more than four hundred times. Mr. Brebner.

The Author had referred to the case of a light placed 100 feet above the sea; but as it was desirable to take an accurate and impartial view of the circumstances, he had, with the aid of Findlay's "Lighthouses of the World," corrected up to 1884, determined the mean heights at which apparatus of the first, second, and third orders were placed, and had found them to be respectively, 210, 180, and 145 feet. The following Table would show that, for these mean heights of the focal plane for first, second, and third order lights, the raising of the focal point required to dip a focal ray to a point distant 1 mile, or even 2 miles, was quite appreciable, and that the raising of the usual oil-lamps by the amounts indicated would distinctly change the inclination of the emerging beams, whilst the effect of similarly raising the carbons of an electric luminary would evidently be still more marked. Hence means of temporarily dipping the light could be usefully applied to the great majority of lights of the first three orders. The Table showed also figures applicable to a refractor of 600-millimetre focal distance used in his system for the second order, in which he need hardly say the light was dipped by movement of parts of the apparatus, the lamp and the lower reflecting prisms remaining

[1] Mémoire sur l'Intensité et la Portée des Phares, p. 132.

Mr. Brebner. undisturbed. The height of focal plane for the apparatus now being made was 150 feet.

Order of Lens.	Focal Length.	Height above the Sea.	Distance of the Horizon.	Rise of Focal Point.		
				For Horizon.	For 1 Mile Spot.	For 2 Miles Spot.
	Millimetres.	Feet.	Nautical Miles.	Millimetres.	Millimetres.	Millimetres.
1	920	210	16·8	3·8	31·8	16·1
2	700	180	15·5	2·7	20·7	10·5
3	500	145	14·0	1·7	12·0	6·0
2′	600	150	14·2	2·1	14·9	9·0

Mr. Brunton. Mr. R. H. BRUNTON referred to the distribution of electric light, over those portions of the sea where it would afford the greatest assistance to mariners. There could be no question that in many cases where electric light had been tried alongside oil light or gas light, the former failed to pierce as far through a thick atmosphere as the latter. However this circumstance might be explained, it could not be denied, and he had observed it frequently. Sir W. Siemens's suggested explanation[1] had not received much scientific confirmation. The correct explanation might probably be found elsewhere, and it appeared as if the Author had furnished it in his Paper. The functions of a lighthouse were performed under varying circumstances. In bright clear weather the lights were most effective, but unfortunately they were, then, not of so great value. It was in the case of fogs, or thick blinding rain, that the extreme value of a light to the mariner became apparent. In both cases all that the mariner needed was to distinguish the light. Brilliancy was absolutely detrimental in fine weather, and was useless, unless by its means thick fogs could be pierced. The light from the electric arc was so concentrated that, by means of the highly scientific and accurate optical apparatus now in use, it could be parcelled out wherever required, with almost mathematical precision. The Author, in so parcelling out the light, sent only a small portion to the sea between the lighthouse and the horizon, but nearly the whole to the horizon. The result of this was, that in clear weather he obtained a light by which he could tell the time from a watch at a distance of

[1] Minutes of Proceedings Inst. C.E. vol. lvii. p. 155.

Mr. Brunton.

14 miles. This must be a source of the greatest inconvenience, if not danger, to mariners, and certainly of no more value than the faintest light which they could clearly distinguish. But this brilliant light was unable to pierce the thick fogs above mentioned for a greater distance than 4 or 5 miles. At that distance from the lighthouse, therefore, what occurred was this: the main power of the light was streaming away high up towards the horizon, without attaining it, while the small portion of the light directed towards the nearer sea was quite unable to reach it. These were the present conditions of electric light by the Author's own showing, and they conveyed a seemingly clear explanation of the alleged failure of electric light in thick weather. The point, however, did not escape the notice of the Author, who suggested the possibility of dipping the light in thick weather, but feared to leave so important a matter to the discretion of light-keepers. In this Mr. Brunton agreed, as the general efficiency of the light under varying circumstances, would be left in the hands of the not very discriminating intelligence of the men usually employed. Further, the practice might occasion the most serious consequences. On sighting such a light, the first question that would arise in the mind of the mariner, in order to judge his distance from it, would be, Is this light dipped, or is it not? Without anything to guide him, a wrong conclusion on this point might lead to disaster. The proper remedy seemed to lie in the direction of distributing more equally the light over the whole illuminated surface of the sea, much in the same way as it was practically distributed by lights with a large focal area and great divergence. The Author had in no way made out a good case for establishing the elaborate and costly machines described in the Paper. He said that at Tino the principal method of illumination was electric light, and that gas-lamps had also been supplied; further, that an oil-lamp had been furnished, in case of failure of the gas. To complete the sequence, it might be suggested that candles should also be supplied, in case of failure of the oil-lamp, and the light would then have been historically, as well as scientifically, interesting.

Sir John Coode.

Sir JOHN COODE observed, that in the latter part of 1885, he had on three different occasions left Sydney Harbour just before midnight, for ports on the coast, and had not seen a double maximum of light, like two distinct flashes. If the Macquarie light had any fault, it would seem to be in its dazzling intensity within a short distance of the shore. He had not remained on deck through the night to observe the effect of the Macquarie light when below the horizon. He might state, however, that in

Sir John Coode. the case of a first-order light (mineral oil) showing a triple flash at intervals of thirty seconds, supplied by Messrs. Chance Brothers and Company under his direction, in connection with the Colombo Harbour, he had on more than one occasion seen distinctly the glow, not only of each group but of each of the flashes of each triplet, when the light itself, which was visible for 20 miles, was altogether below the horizon. In navigating that part of the Indian Ocean near Ceylon, where the currents created by the monsoons were at times of considerable strength, and subject to much variation, the practical value of distinguishing the position of the Colombo light, as above described, was much greater than might be generally supposed.

Mr. Griffith. Mr. John Purser Griffith expressed his admiration of the optical apparatus described in the Paper, which he considered to be unquestionably the best at present in use for the exhibition of electric light from a lighthouse. The description of the arrangements for distributing the light and for increasing the divergence of the beam was extremely interesting. He fully concurred in the great advantages to be derived by the adoption of large optical apparatus. The advantages of gas-engines over hot-air engines were he thought unquestionable, wherever their use was optional. In regard to such proposals as that for dipping the light during fog, he believed this should be done by auxiliary optical apparatus, so as not to interfere with the regular light. It should be laid down as an axiom in lighthouse management, that under no conditions should the normal or clear weather light be reduced in power, or diverted from its ordinary direction. Any light specially used in fog should be auxiliary to this normal light, and if it was desirable to show it in a different plane from the regular light, this should be done by special optical agents. The great distances at which the light of both the lighthouses were seen, even when below the horizon, were closely allied to the subject of "Sky Illumination," which he had advocated many years ago. In the discussion following Sir James Douglass's Paper on "The Electric Light applied to Lighthouse Illumination" read in 1879, he had stated his views[1] as to certain advantages which gas light had over electric light for lighthouse purposes, and expressed the opinion that the efficiency of gas light in foggy weather was due to the height of the flame, and the consequent great vertical divergence of the beam of light, part of which illuminated the upper stratum of fog; and frequently localised the

[1] Minutes of Proceedings Inst. C.E. vol. lvii. p. 163.

lighthouse long before any of the direct rays reached the mariner's eye. It was in this connection that he brought forward what he termed "sky illumination" in foggy weather, and suggested the adoption of auxiliary optical agents to deflect a beam of light upwards during thick weather, in preference to any attempt to pierce a fog by increasing the intensity of the light. Since these suggestions were made, extensive experiments had been carried out at the South Foreland, to test the relative merits of electricity, gas, and oil as lighthouse illuminants. If the sole object was to test the relative penetrating power of the direct rays of these illuminants, the results might be considered satisfactory; but if the aim was to decide which of these illuminants was the best for assisting the mariner to localise a lighthouse in fog, then they could only be considered an instalment to the information sought. One important defect in these experiments appeared to be the adoption of an apparatus not suited for the exhibition of an electric light in lighthouses. If an optical apparatus such as that described in the Paper had been used, it would not have been so frequently necessary to qualify results by explanatory remarks, as had been the case, and which proved that the apparatus was unfit for the exhibition of an electric light for lighthouse purposes, and was therefore unsuitable for the experiments. The observations, however, conclusively proved that no dependence could be placed on the penetrating power of the direct rays, even of the most powerful lights, to warn mariners of danger in fog. Fortunately, for short distances the modern siren was available. Recent experience had more than ever confirmed Mr. Griffith in the opinion that, if properly developed, "sky illumination" might yet prove of incalculable value to the mariner, as a means of localising lighthouses in thick weather at considerable distances. He much regretted that while the South Foreland experiments were in progress, the various points connected with "sky illumination" had not been scientifically investigated. True, a very few experiments had been made in what was called sky flashing, both with gas and with electric light. To produce this effect arrangements were made to lower the burner and carbons, at will, a few inches below the focal plane, thus raising the beam of light some degrees above the horizon. In the experiments recorded, this angle of elevation was much too small, and, as might have been expected, the results were far from satisfactory. It was therefore not surprising that, in the special report of the observations made on these contrivances, the general result was not favourable to their adoption. The present occasion Mr. Griffith.

Mr. Stevenson. leaving the responsibility of judging when this should be done with the lightkeeper. It was a responsibility, however, which in some services, even with oil lights, was entrusted to the keepers, who burned a greater or smaller number of wicks according to the state of the atmosphere; and, in the case of electric lights, there was in charge of the station an engineer who of necessity was a superior man, and with whom the responsibility of seeing such a matter as this carefully attended to might be safely left. Moreover, the Author, in the latter part of the Paper, when describing his proposed economical electric-light installation, himself proposed to give the keepers this authority to vary the power of the light according to the weather. With reference to the use of continuous-current machines, as the generators of electricity in a lighthouse, he had tried all in his power to introduce them at the Isle of May. The difficulty lay in getting a single-arc lamp to burn with sufficient regularity and steadiness with the continuous current, and not in the machines themselves. So great was this difficulty of burning a single arc with a continuous current, that he had to abandon the attempt and be satisfied with alternating-current machines. As to the proposed economical electric-light installation, he agreed that it accomplished what the Author anticipated, provided the single-arc lamp would burn satisfactorily with a continuous current machine. As to the attendance, he could assure the Author, as a matter of ordinary lighthouse management, that two keepers could not overtake the duty; for it must be kept in view that thick and hazy weather occurred not infrequently, and that in long winter nights of sixteen hours' duration, the proposal would involve both men being up watching all night, and working eight hours during the day, making gas and cleaning the engines, which of course was impracticable. Lastly, as to the cost of the apparatus, the Author had advanced no figures on which a judgment could be formed.

Mr. Vernon-Harcourt. Mr. L. F. Vernon-Harcourt observed that, in the course of the discussion of the two Papers on the application of the electric light to lighthouses in 1879, he had pointed out that two objections might be urged against electric light, namely, its deficiency in penetrative power through fogs as compared with gas and oil lights, owing to its containing a larger proportion of highly-refrangible rays; and the glare of its powerful light, which on clear nights rendered surrounding objects, not directly illuminated by it, less discernible on approaching the light.[1] He had suggested

[1] Minutes of Proceedings Inst. C.E. vol. lvii. pp. 114, 115, and 185.

Mr. Vernon-Harcourt.

that the first objection needed further investigation to ascertain its importance, and that the latter might be removed by suitable optical arrangements. He was glad to find that the Author, in the two lighthouses described, had diverted the excess of light from the near sea, where it was objectionable in clear weather, to the horizon, where it was serviceable. The advantage of electric light for lighthouses over gas and oil was due to the greater illuminating power that could be produced within the compass of the lantern, and the compactness of the light, which enabled the rays to be more concentrated by the lenses. Thus the electric light used in the South Foreland experiments had five times the illuminating power of the gas light; and this was increased to twenty times the power by the optical apparatus. On the other hand, these experiments confirmed his opinion as to the comparative want of penetration of electric light through fog; for when the fog was thick, it was found that the proportionate reduction of the electric light was four times that of the gas light, so that the illuminating power of the former became reduced to only five times that of the latter. He gathered from these results that, as electric light, by aid of the optical apparatus, was only equal per unit of light to gas or oil lights in times of fog, if some of its rays were diverted from the near sea to the horizon in clear weather, the light should be dipped in time of fog, otherwise the electric light would have a less efficiency in such cases than the same power of gas or oil light. The cost per unit of light after concentration by the lenses was too favourable a standard of comparison for electric light, except in clear weather; and for efficiency in fog, the cost per unit of illuminating power of the naked lights should be adopted. He fully agreed with the Trinity House Committee on lighthouse illuminants that electric light, owing to its great intensity, was specially suitable as a guiding light; and he would instance Flamborough Head as a good site for its installation, which ships desired to sight and avoid, rather than to approach. In less important, though easily accessible localities, considerations of cost must govern the choice, not omitting from the question the loss of efficiency in foggy weather, which might be provided against, as suggested by the Author, by a more powerful machine in reserve. Though it had been proposed, about four years ago, to encircle the French coast with a belt of electric light, by the establishment of the light at forty-one lighthouses in addition to the five in which it was already exhibited, he understood that this large extension of the light had been abandoned. He considered that the small penetration of the most powerful electric

Mr. Vernon-Harcourt. light through dense fog indicated that no lighthouse establishment was complete without the provision of the most efficient audible signals for use in foggy weather. The range of sounds was limited, and decreased very rapidly with the distance; but a siren trumpet could be heard about 6 miles off, and a greater distance had been quoted to him last summer at Flamborough Head as the range within which the exploding rockets used there were audible. It was possible that an explosion produced the most far-reaching sound, as the firing of large guns was audible at very great distances. The direction and force of the wind greatly affected the range of sounds; but a still foggy atmosphere was favourable to their transmission, and under such conditions a sound could be heard at a distance to which the strongest light could not penetrate.

Mr. Wigham. Mr. J. R. WIGHAM observed that in 1879 he endeavoured to show that the electric light was not a suitable lighthouse illuminant,[1] from practical experience with it, at the clock tower of the Houses of Parliament and elsewhere. He found the electric beam to be far less powerful in penetrating fog than the larger and less intense light of the gas flames which were then used, and were still in use on that tower as the signal light. On referring to the report on the South Foreland experiments, it would be found that in clear weather electric light was greatly brighter than either oil or gas, so much so, as to elicit the following statement by the committee of the Trinity House in their report. "In clear weather" electric light "is certainly not popular with sailors, chiefly on account of its dazzling effect at short ranges," and therefore not suitable "for general adoption around the coast." They intimated that they had been cautious in establishing electric lights, not only because of their great cost, but especially in deference to the ideas of nautical men, that from the dazzling effect of the lights they found difficulty in judging their distance from them. The Author himself stated, with regard to the Macquarie light, that the only criticism from mariners had been that when somewhat near the lighthouse, the flashes were so bright as to dazzle the eye. These objections to electric light for lighthouses in clear weather were, no doubt, worthy of grave consideration, but they sank into insignificance compared with the much more serious objections, that, in fog, when a sailor chiefly required a light, electric light failed him. He considered the behaviour of electric light in fog to be by far the most important point in connection with the question of its employment as a lighthouse illuminant. The

[1] Minutes of Proceedings Inst. C.E. vol. lvii. pp. 77, 168.

report of the committee of the Trinity House on the South Foreland experiments, under the head of fog, showed upon analysis that the average of all the experiments with electric light in fog indicated that it was little more than 3 per cent. better than gas, and 17 per cent. better than oil; but this apparent superiority of electric light, small as it was, was by no means proved by the record of the experiments. On the 24th of November, observations were made at sea, which when examined, showed that in seven out of thirteen, gas was superior in power, both to electric light, and to oil; in one case gas had double the illuminating power of electric light in five cases gas and electric light were equal, and in one only was gas inferior to the electric light. In the observations on land, the first record stated that the result of the observations was distinctly unfavourable to electric light, and it was also stated that it was subsequently ascertained that its beam was not properly directed to the positions occupied by the observers as this, it was said, was the first fog experienced. In other words, the report admitted that when electric light was exhibited as a lighthouse light, with its beam directed upon the horizon and the intervening space, and not specially directed upon observers, it was beaten in fog by both oil and gas. On the next occasion the report stated that Sir James Douglass gave directions that the foci of the electric lights should be directed upon the observers, and then it appeared that the electric light was seen 300 feet further than the flame of oil or gas—a very small advantage considering that the observers obtained the benefit of the whole power of the directed electric beam, all other portions of the space supposed to be illuminated by the electric light being left in darkness. He submitted that such manipulation of the illuminant as a lighthouse light was inadmissible, that deductions as to the behaviour of electric light from the data in the Trinity House reports were not reliable, and that the Trinity House authorities were not justified, even on the showing of their own report, in recommending electric light as a lighthouse illuminant. Mr. Wigham.

He thought no nautical man would advise that the light of a lighthouse should be diminished at any time in any portion of the space intended to be illuminated, at the option of a lightkeeper, or otherwise. To increase the light in time of fog, as was done in the case of the gas light by adding to its volume and intensity twelve times the ordinary clear-weather light, as in the case of Mew Island, was indeed exceedingly beneficial to the mariner; but to abstract from the light sent in the direction of the horizon for the purpose of dipping it upon the sea between the horizon and the

Mr. Wigham. lighthouse, was to place in jeopardy sailors navigating that portion of the sea from which the light had been taken, and this was done at the South Foreland. If the Author, or the advocates of electric light for lighthouses, would undertake that the electric light should (as in the case with gas and oil) send a beam from a lenticular apparatus 18 feet high by 4 feet 6 inches wide, with equal brilliancy to every part of the horizon, and the space intervening between the horizon and the lighthouse, maintaining the same superiority over other lights in foggy weather as in clear weather, then he would consider their case proved. But all experience, as far as he was aware, was against this. At the South Foreland, even when the whole power of the light was directed in one beam on the observers, the utmost advantage that it had over gas or oil was that recorded by Mr. Harold Dixon, when it penetrated 300 feet further, or about a vessel's length. He had no reason to doubt the correctness of Mr. Dixon's measurement; he puts it down at 18½ per cent. of superiority; but those who had investigated the matter with him agreed that the conditions under which the illuminant appeared to have that superiority, were such, as assumed for it an advantage calculated to invest it in the eyes of the public with a superiority which it did not really possess. Those who endeavoured impartially to look into this question, naturally felt that no such fictitious value should have been attached to any of the lights under comparison. In like manner, he thought there was reason to complain of figures that had been made public with regard to the South Foreland experiments; for example, while Mr. Dixon estimated the percentage of superiority of the electric light in fog, under the favoured circumstances above referred to, 18½ per cent., Professor W. Grylls Adams publicly stated it to be 6,000 per cent. It seemed to him, therefore, that the interests of navigation, as well as the safety of seamen, imperatively demanded further investigation, by competent and disinterested persons, of the suitability of electric light as a lighthouse illuminant.

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14 December, 1886.

EDWARD WOODS, President,
in the Chair.

The discussion upon the Paper, on "The Electric Lighthouses of Macquarie and of Tino," by Dr. John Hopkinson, occupied the entire evening.

Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 2055.*)

"Constantinople Water-Works."

By Frederic Briffault, Assoc. M. Inst. C.E.

The city of Constantinople is divided into two parts by the Golden Horn, its eastern shores being bounded by the Bosphorus and the Sea of Marmora. Galata and Pera, the European quarter of the city, stand on the northern side of the Golden Horn, the former on the sea-shore, and the latter on high ground above it; and Stamboul, the ancient and native portion, is on the southern shore; communication is established between them by two iron bridges, which open for the accommodation of shipping, sufficient headway not being obtainable owing to the extreme flatness of the banks. The villages on the European shores of the Bosphorus, namely Ortakeui, Kourouchesme, Arnautkeui, Bebek, Therapia and Buyukdere, have of late years become the summer resort of the wealthier classes of the city, and in estimating the population it is necessary to include these villages.

The existing sewers, or, more correctly speaking, longitudinal cesspools, are square in section, put together in the roughest manner, and consequently rarely water-tight; they are laid invariably with insufficient fall, the solid matters thus remaining in them until they become choked, when portions are opened and cleansed, poisoning the air for hours afterwards. The contents of these channels are finally discharged close to the most densely populated districts of the Golden Horn.

The supply of water has always been limited, and, with such disadvantages, it might well be imagined that the city would be rarely free from epidemics. This happily has not been the case, the most alarming outbreak having been one of cholera in the year 1865, when upwards of two thousand persons perished daily.

A marked improvement has taken place in one portion of the town during the last two years, especially since the tramway lines have been laid down. Part of the Grande Rue de Pera and the Rue Tèpé Bachi are now decently paved, and a spacious club, and

new opera house have been erected, together with several private residences.

The population of Galata and Pera, together with the villages on the European shores of the Bosphorus, is about three hundred and sixty thousand. The highest part of Pera is Chichly, which is 370 feet above sea-level. Stamboul, the ancient city, has a population of about four hundred and twenty thousand persons, and its highest ground is about 260 feet above sea-level. To the above estimate must be added about five thousand for the floating population of the city, making up a total population of about seven hundred and eighty-five thousand persons.

The city is at present supplied from the reservoirs, or "bends" (this being the local term), situated at Chioy, Belgrade, Pergos, &c., the water being conveyed thence by aqueduct to service-reservoirs in different parts of the city. These "bends" are situated on the slopes of a range of hills, which are a south-eastern prolongation of the Balkan mountains. The works were carried out under the later Roman emperors, and both in design and in construction they compare favourably with any work of recent date.

It is only in the details of the distribution that the constructors appear to have shown any ignorance. The pipes which convey the water from the small reservoirs to the public fountains and to some of the houses are of lead, and vary in diameter from 25 millimetres (0·98 inch) to 60 millimetres (2·36 inches); lines of these pipes are laid through the streets and are easily damaged, their thickness being little more than that of a sheet of paper. In many houses large marble cisterns occupy the whole area of the basement, in which rain-water is collected.

The annual rainfall, from observations extending over a series of years, amounts to 71 centimetres (28 inches); but in a dry year, after deducting loss by evaporation and absorption, not more than about 5 inches can be reckoned upon for collection, which (considering the limited watershed available) is a quantity wholly inadequate for such a population as that of Constantinople.

In 1882 a company was formed under the auspices of La Compagnie des Eaux de Paris, with a capital of 20,000,000 francs (£800,000), to procure a supply of water for the city from Lake Derkos, near the Black Sea.

Lake Derkos is a freshwater lake having a depth varying from about 12 to 20 feet, and an area that may be roughly computed at about 10,000 acres. It is cut off from the Black Sea on its north side by sandhills or dunes; the channel between them, a comparatively narrow passage, has now been blocked by dams, so that the

sea is prevented from entering the lake, and the level of the latter has been raised. The water for the present is taken in at Kizil-dere, at the Western extremity of the lake, where the principal feeders flow in. The intake-tunnel commences at this point, and follows the northern contour of the lake through the sandhills until it reaches the well at the pumping-station at Derkos.

The upper portion of the tunnel is laid with open joints, and the water falling upon this large area of sand, to a great extent percolates into the tunnel and thus greatly augments the supply. A main is also laid, with branches and screw-cocks parallel with the tunnel, to draw from the lake itself when desirable.

The pumping-station is situated near the village of Derkos, which is about 29 miles from Constantinople, and $4\frac{1}{3}$ miles from the port of Karabournou on the Black Sea. The level of the floor of the engine-house is 1 metre (3 feet 3 inches) above the highest level of the water of the lake, or 2·5 metres (8 feet 2 inches) above that of the sea.

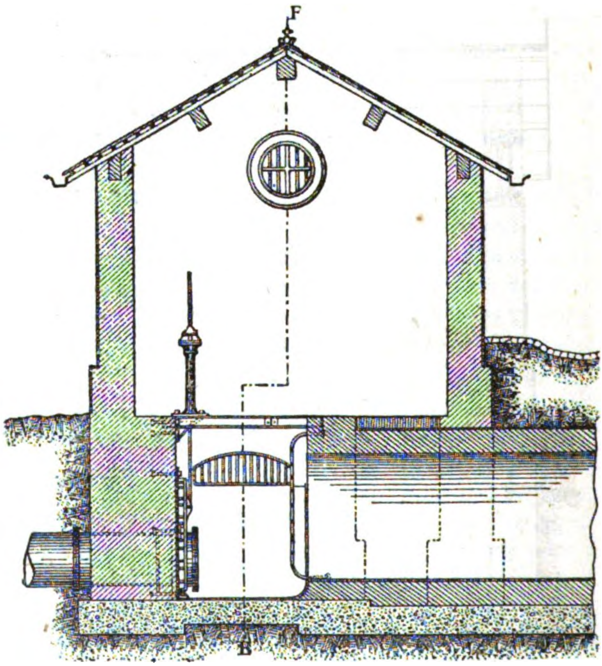
The engine- and boiler-houses have been designed of sufficient dimensions for six pairs of engines and twelve boilers, to furnish a daily supply of 40,000 cubic metres (8,800,000 gallons), but as the company only contemplates supplying 13,333 cubic metres (2,933,260 gallons) for the present, only three pairs of engines and six boilers have been laid down. These collectively are capable of pumping 20,000 cubic metres (4,400,000 gallons) to a maximum height of 125 metres (410 feet) in eighteen hours.

The engines are high-pressure and horizontal, of the direct-acting type, of 600 HP. (French) collectively, driving double-acting piston pumps. Each pair is coupled, but each engine can be worked independently. Their normal speed is 16 revolutions per minute. They have jet-condensers, and the feed-water is supplied to the boilers at a high temperature. The cylinders are 0·9 metre (2 feet 11 inches) in diameter, with a length of stroke 1·8 metre (5 feet 11 inches), and the pumps 0·262 millimetres (10·32 inches) in diameter, having the same length of stroke as the engines. The cylinders are steam-jacketed, variable expansion being effected by two independent slide-valves, one valve for admitting and exhausting the steam, and the other for cutting off at any point of the stroke. Steam is supplied by six double-flued boilers with Galloway tubes at a pressure of 5·25 atmospheres (78 lbs.).

The water is raised to a height of 109 metres (358 feet) through a pumping-main 0·60 metre (24 inches) in diameter, 2·17 miles in length, into a reservoir near the village of Derkos. It is built in

four compartments, having a total capacity of 1,043,539 gallons, and a depth of water of 10 feet. The walls are of limestone rubble, the piers for the arches being of squared stone. Bye-pass pipes and valves are arranged so that the conduit can be supplied direct, without the water passing into the reservoir. On leaving this point the water flows by gravitation through a built aqueduct and siphon-pipes a distance of 26·66 miles to the service-reservoir

Fig. 1.



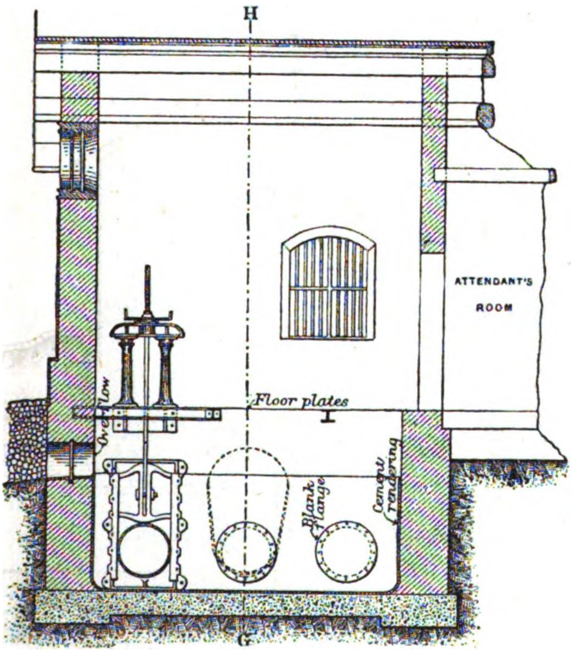
Siphon Inlet-Chamber.
Section on line G H of Fig. 2. Scale ¼ inch = 1 foot.

at Ferekeui, on the high ground at Pera, the top-water level of which is 295 feet above the sea. There are a few short lengths of tunnel on the line of the same form as the aqueduct. The continuity of the aqueduct is broken by valleys fifteen times on the way to Ferekeui. Cast-iron siphon-pipes 24 inches in diameter are therefore laid across them. Their general arrangement in the inlet- and the outlet-chamber is shown by Figs. 1 to 4. The conduit is 5 feet 3 inches in height by 3 feet 5 inches wide. Like the reservoirs, the aqueduct is of rough rubble limestone, rendered in

cement up to the springing of the arch, the crown of which together with the exterior of the siphon-chambers is floated over with a layer of hydraulic lime-mortar. The siphon-wells are rendered in cement up to the water-level.

At the inlets of the longest siphon-pipes, there are buildings with accommodation for an attendant. Sluices are fixed at each of these stations, to shut off the water from each section of pipe in the event

Fig. 2.



Siphon Inlet-Chamber.
Section on line E F of Fig. 1. Scale ¼ inch = 1 foot.

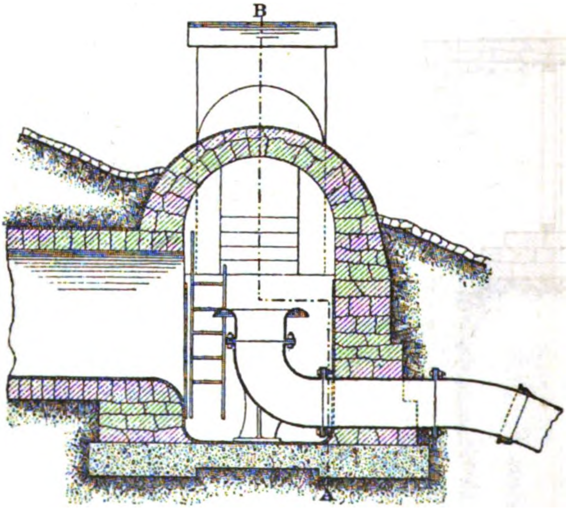
of fracture. The formation through which the aqueduct passes is chiefly schist, which is of considerable depth resting upon carboniferous limestone. This schist or slate rock is in many parts extremely hard, and has given much trouble to dislodge. The surface soil is principally clay. For the present, only one siphon-pipe 24 inches in diameter has been laid down, which is sufficient for the present supply of 13,333 cubic metres (2,933,260 gallons); as the demand increases two more will be added, the three pipes giving the full supply for which the aqueduct has been con-

structed. In the fifteen siphons before mentioned there is a length of about 6·66 miles of cast-iron pipes, and about 20 miles of aqueduct and tunnels.

The difference of level between the reservoir at Derkos and the service-reservoir at Pera is 19·50 metres (64 feet). This gives a fall of 2·4 feet per mile, which is proportioned between the aqueduct and the pipes.

In order to supply Chichly, the highest part of Pera, it has been necessary to construct a small reservoir at the former place, the

FIG. 3.



Siphon Outlet-Chamber.
Section on line C D of Fig. 4. Scale ¼ inch = 1 foot.

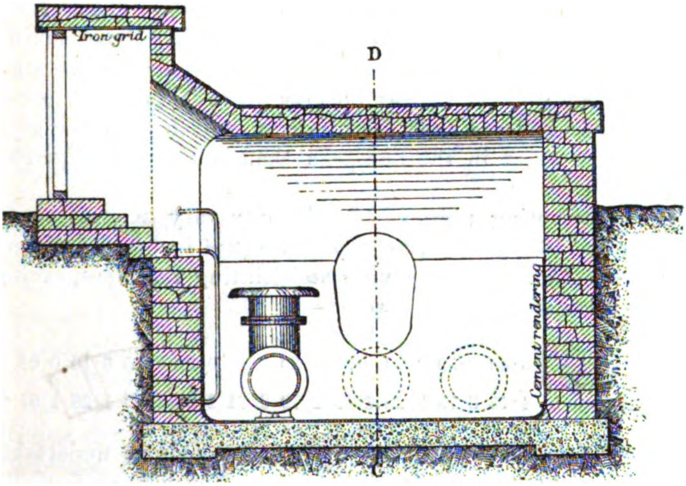
top-water level of which is 114·50 metres (375 feet) above the sea. To accomplish this a turbine has been fixed at a point 82 feet below the Ferekeui reservoir, a supply-pipe 0·40 metre (16 inches) in diameter being led therefrom to the turbine. This gives the necessary power to work the pumps, and raise the water to a height of 162 feet, which gives ample pressure for this district. The water for working the turbine is led into the main for furnishing the European shores of the Bosphorus.

There are three equilibrium reservoirs for the villages of the Bosphorus, all of which are constructed in two compartments; the details are as follow:—

——	Capacity of each Division.	Depth of Water.	Height above Sea.
	Gallons.	Feet.	Feet.
Arnautkeui	550,000	13·77	170·50
Boyadkeui	330,000	10·82	137·77
Kiretche Bournou . . .	165,000	10·82	105·00

The reservoirs at Ferekeui and Chichly are also built in two divisions, each compartment of the former holding 1,760,000

FIG. 4.



Siphon Outlet-Chamber.
Section on line A B of Fig. 3. Scale ¼ inch = 1 foot.

gallons, and having a depth of water of 16·40 feet. The latter contains 770,000 gallons to the compartment, and has a depth of 16·40 feet. All six are covered reservoirs, built of limestone rubble and rendered with a thickness of 1 inch of cement mortar to the top-water line.

There are thus three services, one high at Chichly, another intermediate, at Ferekeui, and the third low for the Bosphorus; by an arrangement of valves they can all be coupled together and the water made to circulate. Loaded safety-valves are fixed on the pumping-main and self-acting double air-valves on the siphon-pipes on all the crests, and wash-out-valves in the depressions; lead and yarn joints have been employed throughout.

The transport of the large pipes was a matter of difficulty, owing to long distances to be traversed, and the badness of the roads in winter, but more especially from the trouble of obtaining labourers. The breakage in discharging the pipes and castings from the steamers to the lighters (there being no quays suitable for vessels to come alongside), and from the latter to the shore was very great at the commencement. The siphon-pipes were $\frac{11}{16}$ inch thick, and weighed on an average 19 cwt. each.

It may be thought that the quantity of water provided is very small for such a population as that of Constantinople; but no industry worthy of the name is carried on. No breweries nor works of any kind require large supplies of water, the only large consumers being the hotel and restaurant proprietors, and a fair supply for the Sultan's palaces. Too much reliance must not be placed upon the whole of the native population, amongst a large portion of which great poverty prevails, taking the water. The Author believes that the company will have a far greater sale for the water in the European than in the native quarter of the town.

The distributing pipes within the city vary in diameter from 0·35 metre (13·8 inches), to 0·06 metre (2·4 inches). The prices paid per lineal metre for laying and jointing the pipes, exclusive of excavation and filling in, were:—

Diameter of pipe in metres . .	0·60	0·50	0·40	0·35	0·30	0·25	0·20	0·15	0·10	0·08	0·06
Price in francs .	4·45	3·75	3·26	3·08	2·79	2·74	2·37	1·93	1·28	1·01	0·52

The laying of most of these pipes was a tedious undertaking, principally from the number of sewers met with every few yards, and the trouble of diverting and making them good; there was no possible means of avoiding them. They were encountered at varying depths, and crossed the streets in the most erratic manner. In numerous cases the houses had to be shored up where the pipes passed at close quarters, as many of them have hardly any foundations, and there was danger of bringing them down altogether. The dead-ends of the small pipes are connected to other mains wherever practicable, to prevent the water becoming stagnant.

A limited number of fire-hydrants has been fixed. These are of the screw-down kind, with gun-metal spindles and loose valves with leathern washers enclosed in lock-up surface-boxes. The number, however, will have to be greatly augmented, as the fires occurring in the city are very numerous, and the loss of life in

consequence is very great; and, up to the present time, no practical means have been adopted for extinguishing them.

The house-services are arranged on the French system, with the clip round the service-pipe, and the plug-cock screwed into it, the piping is of lead, varying from 13 to 55 millimetres (0·51 inch to 2·16 inches) in diameter.

In the town-mains, the pressure of water is equal to a head of from 50 feet to about 280 feet in the low parts of the city.

The consumers will be chiefly supplied by Fragert's double piston meter. The average charge per cubic metre (220 gallons) will be 3·5 piastres, 7¼*d.* (2*s.* 8¾*d.* per 1,000 gallons), special arrangement being made by the year for the larger consumers.

The works were commenced in the spring of 1883, and were completed in January 1885, and opened on the 26th of that month.

Mr. Paul Bouton, Ingénieur en Chef des Ponts et Chaussées of Paris, was the Chief Engineer and Director of the works. The aqueduct and the reservoirs were carried out by local contractors —the average cost of the aqueduct per lineal metre having been 95 francs.

The engines and boilers were constructed by La Compagnie de Fives-Lille (Nord), France, for 600,000 francs. Messrs. Dalmas & Cie., of Marseilles, supplied the house-service fittings, and all laying on to the houses. The pumping-main, siphon-pipes, distributing-mains, and special castings, in all about 9,340 tons of cast-iron, were supplied by Messrs. R. Laidlaw & Sons, and Messrs. Thomas Edington & Sons of Glasgow. The sluice-valves, sluices, hydrants, &c., have been provided by the Glenfield Company of Kilmarnock, N.B.

At the present time (October 1886) four thousand houses in Pera are being supplied by this company, equal to a consumption of about 50,000 gallons of water per day; and it is anticipated that this quantity will be more than doubled within the next twelve months.

The Paper is accompanied by several diagrams from which the Figs. in the text have been prepared.

(*Paper No. 2123.*)

"Effect of Temperature on the Strength of Railway Axles."

PART I.

By Thomas Andrews, F.R.S.E., Assoc. M. Inst. C.E., F.C.S.

The behaviour of metals exposed to sudden impact under varying conditions of temperature, does not appear to have received that careful experimental attention on a large scale which the importance of the subject deserves, not only from its intimate connection with all classes of railway work, but also in relation to structural ironwork generally.

The Author, having been engaged twenty-three years in the manufacture, examination, and testing of railway axles, &c., at the Wortley Ironworks, near Sheffield, which have been in the occupation of his family for two generations, and were in operation previous to the year A.D. 1660, trusts that a record of his experiments in the above direction may not prove unacceptable.

The object of the present research was to investigate the effects of varying temperature on the resistance to impact of railway axles. It has been already shown by careful experiment "that the absolute or tensile strength of iron and steel is not diminished by cold,"[1] and this under certain conditions may, pending evidence to the contrary, be accepted as an established fact, so far as relates only to the resistance to tensile-strain or steadily applied pressure. Transverse sudden impact under similar conditions of low temperature appears to produce a different effect, which has hitherto received only a limited experimental attention, at least on the full-sized scale, possibly owing to the difficulty and considerable cost of such experiments—the problem requiring solution was therefore involved in some obscurity. The serious Newark accident in 1869, from the breaking of a steel tire during severe frost, directed public attention to the subject. Shortly afterwards, the eminent physicist, Dr. Joule, made a series of experiments "On the alleged action of cold in rendering iron and steel brittle,"

[1] "Iron and Steel." By Knut Styffe, p. 111.

and inferred therefrom that "Frost does not make either iron (cast or wrought) or steel brittle;" and Mr. Peter Spence arrived at a similar conclusion in his experiments.[1]

About the same time Mr. Brockbank also recorded the result of his investigations in the same direction, which led him to a decision the reverse of Dr. Joule's.[2] Observations on the influence of temperature on the tensile-strength of metals were previously made by the late Sir W. Fairbairn, and also by Mr. D. Kirkaldy. Some recent interesting experiments are recorded in a Paper by Engineer-in-Chief E. Cornut, read on the 10th and 12th of September, 1882, before the North of France Association of Steam-Boiler Proprietors.

Other authorities on the resistance of metals at high temperatures are Mr. Walrand,[3] Mr. Charles Huston,[4] Mr. Greiner,[5] Mr. Kollmann and Mr. C. R. Roelker.[6]

The above observations, however, relate chiefly to the influence of temperature on the tensile endurance, &c., under steady pressures. The Author would also refer to the experiments on rails by Mr. C. P. Sandberg, and to the observations of Mr. J. J. Webster, which relate to the effect of temperature on the resistance of metals to impact,[7] though it is to be regretted that this portion of the latter gentleman's experiments were, in the case of wrought-iron, limited to twelve bars of common iron, only $\frac{7}{8}$-inch square; they afforded nevertheless a valuable indication. Mr. Knut Styffe does not appear to have touched experimentally on the question of impact, transversely applied, although he has expressed some views thereon.

Valuable and interesting as these previous experiments have been, the Author thought that more extensive and elaborate observations on the full-sized scale were required; as it may be surmised that the behaviour of large forgings such as railway axles would vary somewhat from that of rails and smaller rolled bars, the influence of size, form, and manipulation would affect results. It could not be expected that experiments made with small rolled bars should approximate so nearly to the truth

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[1] "The Chemical News." Vol. xxiii. pp. 101, 109 and 124.

[2] *Ibid.* p. 62.

[3] "Annales Industrielles," 1882, vol. i. p. 748.

[4] "Annales des Mines," 1878.

[5] Bulletin de l'Association des Ingénieurs sortis de l'école de Liége. 6 Mai, 1881.

[6] Journal of the Franklin Institute. Vol. cxii. 1881, p. 241.

[7] Minutes of Proceedings Inst. C.E. vol. lx. p. 161.

as those made on full-sized railway forgings, manipulated in every way, both as regards quality of material, workmanship, and form, precisely as those actually running.

The task imposed was felt to be no easy one, and numerous obstacles and difficulties presented themselves from time to time during the progress of the research. It is to be hoped, however, that the indicative results now presented, though not so complete as the Author could desire, may be regarded as on the whole fairly satisfactory.

Referring again to Mr. Webster's Paper, both in that memoir and also during the discussion following, much practical testimony was adduced relating to the destructive effects on iron and steel noticed generally during prevalence of low temperatures. There appeared, moreover, a consensus of opinion, supported by many quoted facts, that in practice many more breakages occurred in railway iron and steel during seasons of cold than in summer heat; especially so in countries where the cold of winter is either extreme or liable to rapid variation, as in some parts of Russia, where the winter temperature not unfrequently varies from 0° to −40° Centigrade; in Norway, where it is sometimes as low as from −20° to −40° Fahrenheit; and in North America, − 30° or −40° Fahrenheit.

The following information relates to the average summer and winter temperature in Canada for the past ten years; and the Author is indebted to the Department of Marine, Meteorological Service of Canada, for the record of winter and summer temperatures at stations contiguous to the Grand Trunk Railway of Canada.

McGill College Observatory, Montreal. September 7th, 1885.
Record of Temperatures. (In degrees Fahrenheit.)

Month	December.	January.	February.
	°	°	°
Average Temperature during the past 10 years	+ 18·9	+ 11·8	+ 17·3
Lowest " " " 10 "	− 25·2	− 26·0	− 24·0
Month	**June.**	**July.**	**August.**
Average Temperature during the past 10 years	64·6	68·9	68·2
Highest " " " 10 "	90·7	93·9	92·2

METEOROLOGICAL SERVICE OF CANADA—TORONTO DEPARTMENT OF MARINE.
October 15th, 1885.

Statement of Temperature at Toronto, and at several Stations contiguous to the Grand Trunk Railway.

Stations.	Winter. December, January and February.				Summer. June, July and August.			
	Mean Temperature.	Absolutely Lowest Mean Temperature.	Mean of the Lowest Minimum Temperatures.	Lowest Minimum Temperature in period.	Mean Temperature.	Absolutely Highest Mean Temperature.	Mean of the Highest Maximum Temperatures.	Highest Maximum Temperature in period.
	°	°	°	°	°	°	°	°
Toronto . . .	23·8	17·3	− 12·4	− 26·5	65·3	68·3	90·6	99·2
Brampton . .	22·1	15·9	− 16·1	− 23·2	67·6	68·2	91·4	97·0
Guelph . . .	21·1	*	− 20·6	− 35·0	66·1	*	89·6	98·0
Woodstock . .	22·1	15·6	− 19·7	− 33·6	65·9	67·9	92·1	99·4
London . . .	23·5	17·1	− 19·6	− 25·0	66·1	70·3	91·3	98·2
Granton . .	24·3	17·6	− 9·2	− 18·5	66·6	69·6	89·2	93·0
Stratford . .	21·4	11·7	− 16·2	− 31·0	65·6	67·8	89·8	98·5
Goderich . .	24·3	17·6	− 9·2	− 18·5	66·6	69·6	89·2	93·0

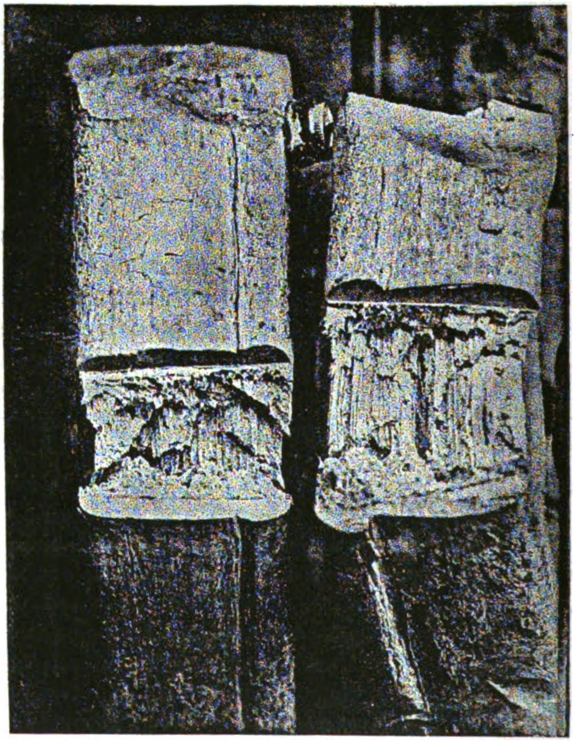
* Too short a period to afford a fair comparison.

With reference to the breaking of a wagon-axle at Penistone, on the 1st of January, 1885, the Author ventures to surmise that the prevalence of low temperature previous to and at the time of that accident was instrumental in producing the fracture of the axle in question, as a temperature of about 24° Fahrenheit had prevailed for above a week previous to the accident. It may be mentioned, however, that neither these axles nor the steel crank-axle mentioned below were of the Author's manufacture. The preceding view is further strengthened by the circumstance that several other wagon-axles were fractured within a few days in that district, and during the same frosty weather. Other causes were doubtless also involved, as the axle which caused the accident had apparently been running seventeen years, and must consequently have undergone much "fatigue." Moreover, the permanent-way would be considerably hardened, which in winter has always a greater tendency to induce fractures in railway iron-work.

The fracture of the steel locomotive crank-axle (which had only

been running about fourteen months) at Penistone, on the 16th of July, 1884, was attributed to other causes than temperature, viz., the presence of an unsuspected internal growing flaw in the metal. The atmospheric temperature on the day of the accident was about 70° Fahrenheit. It may perhaps, however, here be incidentally mentioned that Chief Engineer Isherwood, of the United States Navy, has indicated that steel shafts (accidentally heated at necks

FIG. 1.



or journals), under certain conditions of warm temperature, become more brittle, and in this state more liable to fracture than wrought-iron.

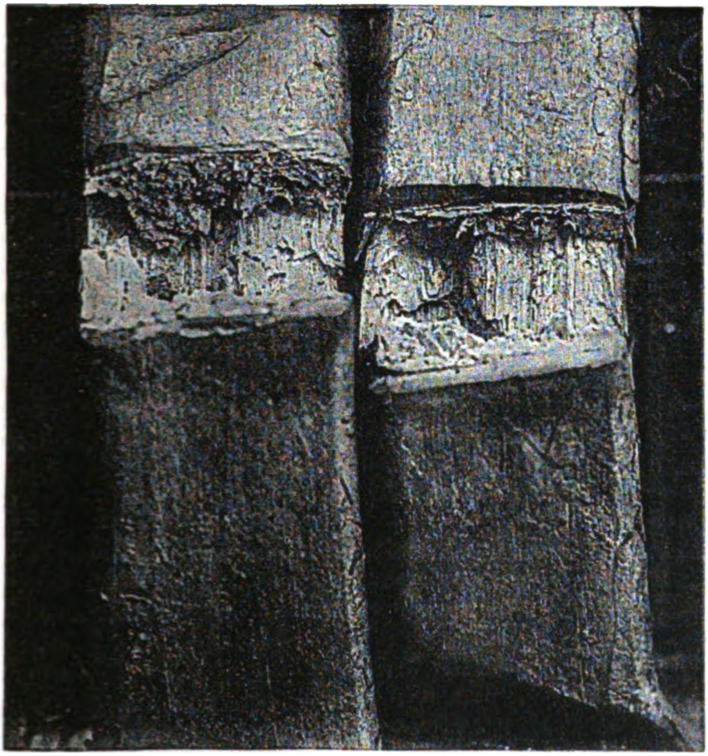
Having, shortly after these accidents, made an inspection of both broken axles, the Author thought it might not be irrelevant to make these few remarks.

The experiments recorded in this Paper indicate that a variation of temperature affects the resisting strength of railway axles under

the force of heavy sudden impact. It may hence be inferred that the material of which an axle is made, although suitable for use in a hot climate such as India, might not perhaps prove so serviceable in colder or arctic climes, and *vice versâ*.

The extract below from a letter by Mr. Wallis, Mechanical Superintendent of the Grand Trunk Railway of Canada, to Mr. G. Reaves, expresses his experience of the effect of temperature in

Fig. 2.



that country on axles, &c.: "I may say, for Mr. Andrews' information, that although it is difficult to arrive at actual relative facts, under so many different conditions of working, as to load, iron, and manufacture of axle, &c., &c., there is no doubt that the breakage, both of axles and tires (all other conditions except that of temperature being equal), is greatly influenced by the severity of the climate in winter."

It would appear that of a total of fifty-six tender- and car-axles

broken on the Grand Trunk Railway during the year 1884, only twenty-three occurred during the summer months, and the remaining thirty-three during the winter season; and the breakages of engine-axles in the year 1884 were three, one of which occurred in March and two in December. But, as Mr. Wallis remarks, the conditions under which the axles broke might vary to some extent. From causes connected with temperature it has been noticed that the breakages of steel tires in Russia were 50 per cent. more in winter than in summer. It has also been remarked that in North America the effect of low temperature produced a larger number of fractures, especially of steel tires, where the skeletons were rigid cast-iron or wrought-iron.

The same observation also applies to the relative action of summer heat and winter cold on railway axles in the United Kingdom, and other temperate countries.

A more immediate object of the Author's research was to endeavour to determine the comparative effect of temperatures, within a moderate range of actual experience, on the resistance and strength of railway axles exposed to sudden impact under varying conditions of high and low temperature. The rough method of testing by the sudden impact of a heavy weight falling some distance was adopted, as more likely to approximate to the sudden and heavy shocks of practical railway work, and the distance the testing ball was allowed to fall was selected, after careful consideration, as generally suitable for the purposes of this inquiry, though perhaps a less drop might have been preferable in some respects as affording a test of more even character. The hardening and solidification of the whole of the permanent way during the prevalence of low temperatures has been assumed by Dr. Joule, Mr. Styffe, and others, to be, if not the sole, probably the chief cause of liability to breakage on railways in frosty weather. Styffe has demonstrated that, under certain conditions of low temperature, the resistance of the timber of the permanent-way is increased by about 12 per cent.[1] The Author, however, agrees with Mr. Sandberg in not accepting this as the prime factor in the case, although to a certain extent it is necessarily involved. To eliminate this source of error from the experiments now recorded, the Author took the precaution of making his observations under known conditions of atmospheric temperature. The detail of the methods adopted is more fully described later on, from which it will be seen that the tests generally were of an

[1] "Iron and Steel." By Knut Styffe, p. 113.

extensive and severe character, requiring the greatest care, and that they occupied a very considerable time in completion. Forty-two complete railway-axles were tested and used in the course of the research; and above 61 tons of snow, ice, and salt, were consumed. The wrought-iron forgings employed were full-sized Best Best faggoted scrap railway-carriage axles, made primarily from clean selected scrap iron, worked and afterwards forged into axles by methods in vogue at the Wortley Ironworks about fifty years. The brand of the axles was that generally known as "Wortley Best Best."

A general idea of the structure and fibre of the iron faggots from which the axles were made will be obtained on reference to Figs. 1 and 2.

TABLE I.—TENSILE-STRAIN TEST of a BEST BEST SCRAP RAILWAY-CARRIAGE AXLE turned down to 2¼ inches diameter, and a portion from another axle turned down to 1½ inch.

Original.		Ultimate Stress.		Ratio of Elastic to Ultimate.	Contraction of Area at fracture.	Extension.		Appearance of Fracture.
Diameter.	Area.	Elastic per sq. in.	Ultimate per sq. in.			At 40,000 lbs. per sq. in.	Ultimate.	
Inch.	Sq. in.	lbs.	lbs.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
2·257	4·000	23,800	48,372 (21·59 tons.)	49·2	25·3	4·79	19·7	80, fibrous. 20, crystalline
1·597	2·000	28,200	48,790 (21·78 tons.)	57·7	26·3	3·53	17·9	100, fibrous.

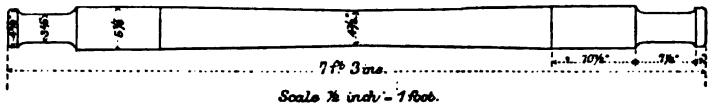
The diameter of the axles did not allow of the forgings as a whole being placed under tensile-strain (and such a test might not perhaps serve a useful purpose), but the above sufficed to indicate the quality of the iron in the interior; and doubtless nearer the surface, and with the "skin" on, the iron would endure a somewhat greater ultimate stress. These test-axles were the same in quality and manufacture as those employed in the cold and the warm testing.

The axle-tests were arranged in this Paper into Sets I, II, and III.

The axles used in Set I and Set II were made from rather smaller scrap than those employed in Set III, but were otherwise worked under equal conditions. The fractures of the axles in Sets I and II appeared consequently to manifest generally a rather finer grain (Plate 10). These forgings afforded for the

research a fair representative selection from a class of best best scrap iron railway axles usually employed in practice for railway carriages. To ensure as near as practicable a uniform molecular structure, quality and standard of workmanship, the whole of the forgings were submitted to similar treatment; and the same furnaces, machinery and hammers were employed throughout. The forgings were made to a well-known railway specification to which the Author has supplied many thousands of axles, and when finished they were each exactly of the dimensions given on Fig. 3; the weight of each axle was 3 cwt. 3 qrs. 5 lbs.

Fig. 3.



Scale ½ inch = 1 foot.

The greatest care was exercised in endeavouring to preserve practical uniformity during manipulation. The chemical analysis of the finished forgings showed the composition as under.

Table II.—Chemical Analysis of the Axles.

Description.	Combined Carbon (by colour test.)	Silicon.	Sulphur.	Phosphorus.	Manganese.	Iron (by difference).	Total.
Sets I. and II. .	0·068	0·158	0·007	0·108	0·360	99·299	100·000
Set III. . .	0·038	0·117	0·019	0·246	0·112	99·468	100·000

Method of Experimentation.

The apparatus for testing was constructed as follows. The two grooved supports on which the axle was laid (to receive the impact of the weight allowed to fall on its centre) were heavy metal castings, let in and firmly secured to a heart of oak bed-plate 7 feet 10 inches long, 3 feet 7 inches wide, 12 inches thick, resting on a suitably firm ashlar foundation, which in turn reposed at a convenient depth from the surface, on solid ground. Railway axles have been regularly tested on this spot for many years. The foundation was placed at a sufficient distance below ground to afford an additional protection against error, the supports being thus removed beyond the consolidating influence of frost on the surface of the ground, the whole constituting a suitably rigid base on which to make the experiments.

Adjacent to the testing apparatus was placed a large wooden tank A used for immersing the axles in the freezing mixture, as described further on. The tank was pierced with small holes at the bottom for the water to escape. A cast metal water-tank B, attached to which was a stove with damper, chimney, &c., for effectually regulating the various temperatures required, was employed in the capacity of a water-bath for obtaining the higher temperatures.

The jib-crane C, with appropriate tackle, was erected in a convenient situation between the hot and the cold tanks for rapidly removing the axle from either tank to the testing-apparatus. A double-purchase crab with three sheaved blocks, worked in connection with a tall, strong wooden tripod 30 feet high, was used for raising the testing ball to any needed elevation. The falling weight was of tough cast metal weighing exactly 1 ton; it was somewhat pear-shaped and rounded at the bottom. It was arranged to fall from any height (measured by accurate gauges) by means of an easily worked catch-hook attached. A ground plan showing the general arrangement is given by Fig. 4.

The experiments were arranged into cold and into warm tests in the following sets.

Set I.—Observations on the resistance to impact of best best scrap iron railway-carriage axles, tested at a temperature of 212° Fahrenheit, compared under equal conditions otherwise with the behaviour of axles of the same size and manufacture, but at the low temperatures given in Table VI. These tests should manifest some approximation to the conduct of axles under impact, which may have become abnormally heated from accidental causes near the journals.

Set II.—Observations on the resistance to impact of best best scrap iron railway-carriage axles, having a temperature of 120° Fahrenheit, compared under equal conditions otherwise with similar axles tested at the lower temperatures stated on Table VII.

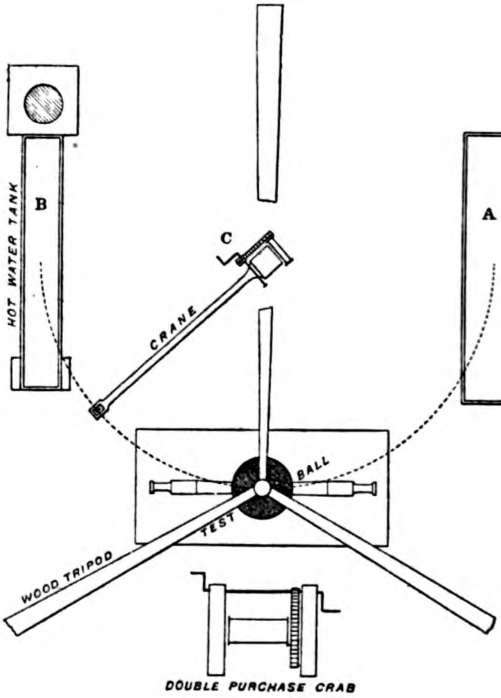
The last named warm tests were made at this heat to afford some indication of the probable effects of temperature on axles in more tropical climes when under impact.

Set III.—Experiments on the resistance to impact of best best scrap iron railway-carriage axles, having a temperature of 100° Fahrenheit, compared under the same conditions otherwise with axles at the lower temperatures recorded on Tables VIII and IX. This temperature was selected as affording an approach to the occasional summer heat of temperate countries, and to the atmo-

spheric conditions in the shade of the Indian and similar climates. Some experiments on plain, round-hammered iron shafts, under the temperature conditions of Set III, are recorded in Table VIII.

It will be observed that most of the low-temperature experiments were purposely made, not at the minimum attainable degree of cold, but rather within the practical limits of the winter of the temperate zone, though in Russia, Canada and other countries the

FIG. 4.



Scale 1/6th inch = 1 foot.

intense cold to be contended with is frequently greater. Some of the higher temperatures of the experimental observations were likewise selected as not inappropriate in practical application to summer heat occasionally obtaining.

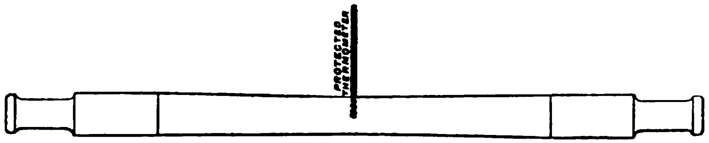
THE COLD TESTS.

A quantity of a freezing mixture, consisting of 2 parts by weight of snow or powdered ice, and 1 part by weight of salt, sufficient for the complete immersion of several axles, was pre-

pared and placed in the tank A, which contained a thermometer; the indications of this were frequently taken, and always registered a constant temperature of $-4°$ Fahrenheit. Whenever required the freezing mixture in the tank was promptly renewed. The atmospheric temperature throughout the investigation was also simultaneously taken, and, so far as possible, the operations were conducted under such conditions as to avoid the hardening effects on the ground or supports that might have arisen, had the observations been taken during a severe winter.

It was considered important to ascertain the temperature of the axle under examination with exactitude; the matter was accomplished thus; in addition to the axle tested, another axle was placed in the same tank A equally surrounded and covered over with the freezing mixture. A hole $\frac{3}{8}$ inch in diameter and $2\frac{1}{4}$ inches deep was drilled in the centre of this axle (Fig. 5),

Fig. 5.



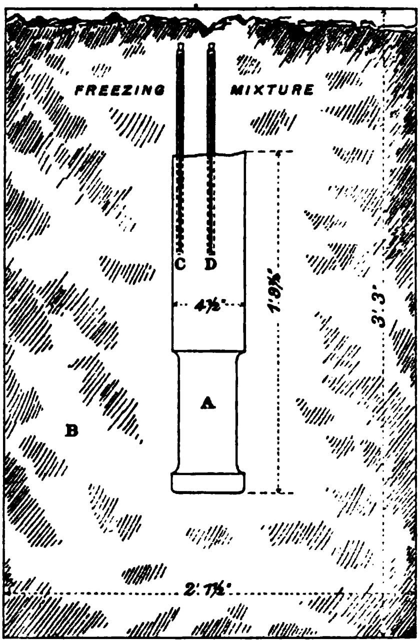
into which was inserted a standard thermometer, the upper part of its stem being protected by means of an iron pipe from direct contact with the freezing mixture; this prevented any moisture accidentally getting in the hole and congealing; the pipe was further closed at the top by a cork to guard the thermometer from external atmospheric influences; experience proved the necessity of these precautions. The thermometer was regularly withdrawn at the stated periodical intervals of testing, and its indications recorded. A considerable number of repeated observations under the same conditions confirmed the measurement of the temperature of the axles given in the Tables.

It might perhaps be considered that the axles were cooled too suddenly (the rate at which this was accomplished is given on Tables III and IV); and it should be remarked that the axles before immersion in the freezing mixture were at the atmospheric temperature recorded in each Table. As they were manufactured during the winter, their normal point of rigidity was comparatively low, and is also recorded on each Table, from which it will be seen there was no great variation in this respect; furthermore the normal point was about midway between the low and the high temperatures of testing. There would probably be on immersion

in the freezing mixture considerable chilling and consequent abnormal molecular change for some distance from the surface, and Tables III and IV show how the cooling took place. But practically in cold countries, and even in Great Britain, rapid reduction of temperature frequently occurs.[1]

It would seem, however, that the strength of some of the axles, tested in the cold, was materially affected by the first sudden chill on immersion in the freezing mixture, some of them appearing to

Fig. 6.



have been more influenced in this respect than others, though the conditions were practically identical.

To reduce an axle to 0° Fahrenheit, immersion in the tank for fully two and three quarter hours was necessary, and although left therein for seventeen hours, a regular series of observations of the internal temperature of the axle showed that it remained at 0° Fahrenheit exactly, although the thermometer registered − 4° Fahrenheit as the constant temperature of the freezing mixture in which the axle was immersed.

[1] Minutes of Proceedings Inst. C.E. vol. lx. p. 235.

The following experiment was also made to illustrate the relative rate of cooling between the surface and the centre of an axle under the conditions stated on Table III, and affords an indication of the mode in which railway axles adapt themselves internally to temperature changes. Two holes C and D ($\frac{3}{8}$ inch in diameter) were longitudinally drilled, one in the centre of an axle forging A, and the other close to the outside; into these two standard thermometers were placed, the upper stems of which were protected by iron pipes closed at the top with corks; the whole was immersed upright in the centre of an iron tank B and completely covered and surrounded with a freezing mixture; the temperature of the freezing mixture was also taken by another thermometer. The thermometers were simultaneously withdrawn, and the results given on Table III indicate the difference between the internal and external temperature of the axle, and show the time required for thermal uniformity to obtain throughout the forging. The arrangement will be understood on reference to Fig. 6.

TABLE III.—ATMOSPHERIC TEMPERATURE during the EXPERIMENT. 44° F.

Time from Commencement of Experiment.	Temperature of Freezing Mixture.	Temperature near Outside of Axle.	Temperature in Centre of Axle.
	° F.	° F.	° F.
Commencement.	..	45	48
1 Minute.	..	42	45
6 Minutes.	..	34	37
11 "	0	30	34
16 "	− 4	26	28
21 "	− 4	24	27
26 "	− 4	22	25
31 "	− 4	21	22
36 "	− 4	20	20
41 "	− 4	18	19
46 "	− 4	18	18
51 "	− 4	18	18

These observations on the internal and external temperature of the axle were taken at frequent intervals for twenty-seven hours. The axle reached a temperature of 0° Fahrenheit in two hours forty-five minutes from first immersion; but no difference was noticed between the internal and external temperature of the forging beyond fifty-one minutes from commencement, the rate of cooling being thenceforward uniform throughout the metal. The observations, however, were prolonged to investigate the matter fully.

TABLE IV.—GRADUAL RATE of COOLING of the AXLE in the FREEZING MIXTURE.

Time from Commencement of Experiment.	Temperature of Freezing Mixture.	Temperature of Axle.	Time from Commencement of Experiment.	Temperature of Freezing Mixture.	Temperature of Axle.
	° F.	° F.	Hours Mins.	° F.	° F.
Commencement.	−4	50	8 30	−4	7
Hrs. Mins.					
0 15	−4	23	9 0	−4	7
0 30	−4	19	9 30	−4	7
0 45	−4	16	10 0	−4	7
1 0	−4	10	10 30	−4	7
1 30	−4	10	11 0	−4	7
2 0	−4	10	11 30	−4	7
2 30	−4	10	12 0	−4	7
3 0	−4	10	12 30	−4	7
3 30	−4	9	13 0	−4	7
4 0	−4	8	13 30	−4	7
4 30	−4	8	14 0	−4	7
5 0	−4	7	14 30	−4	7
5 30	−4	7	15 0	−4	7
6 0	−4	7	15 30	−4	7
6 30	−4	7	16 0	−4	7
7 0	−4	7	16 30	−4	7
7 30	−4	7	17 0	−4	7
8 0	−4	7	17 30	−4	7

The temperature of the test-axles in Table IV did not reach 0° Fahrenheit, owing to their periodic removal from the freezing mixture to and from the testing apparatus, and consequent regular frequent exposure to the warmer atmosphere in the same manner as during the periods of testings.

At the commencement of each test the axle under examination was allowed to remain in the tank for one hour, the internal temperature of the axle at the various periods of impact given in all the Tables was known from the record of the thermometer in the centre of the other similar testing-axle placed in the same tank. The temperature testing-axle was removed from the tank, and reimmersed at the same times as the one undergoing the test of impact, so that an exact indication of the time-temperature might be obtained. At the expiration of the first hour each axle under examination was rapidly removed by the crane, and carefully adjusted on the supports, 3 feet 6 inches apart, of the testing apparatus. The ball was allowed to fall on the centre of the axle from the elevations recorded. The axle was then reimmersed in the freezing mixture for fifteen minutes, again withdrawn and placed on the testing apparatus, receiving another blow from the ball, but in a reverse direction from the first, as the axles in each case were half turned over after every blow. The

object in view was to distort and disturb the fibre of the iron more effectually, so as more readily to approximate to heavy concussions and shocks occurring in actual practice. The Author would here remark, that although in course of testing axles generally the method of reversing the position after each blow is in favour with some engineers, he is not disposed under all circumstances to endorse this method, which in some respects is open to objection.

The axle was then replaced in the tank for a further fifteen minutes, and the operation periodically repeated in the same manner until fracture occurred. The resultant permanent deflections were carefully measured after every blow.

The Warm Tests.—These were conducted as follow:—The axle to be examined was placed in the warm-water bath B (Fig. 4), in which a thermometer indicated the temperature required. The axle was allowed to remain therein for one hour,[1] and was then quickly removed by the crane, and duly adjusted on the testing apparatus, and received a blow from the falling weight. The axle was afterwards replaced in the warm-water bath for fifteen minutes, was again placed in position on the testing machine, being half turned round after each blow, as in the case of the cold tests, and the above operation was periodically repeated until fracture ensued, the results having been carefully noted.

Photographed Fractures.—As soon as an axle was broken, either during the cold testing or warm testing, the bright fracture was minutely examined, washed, and sponged with pure alcohol, and the end prepared for photographing with the least possible delay, which ensured the preservation of the exact appearance of each fracture under the conditions recorded.

It occurred to the Author that as a point of fracture exhibits the lines of greatest weakness, a careful study, examination, and comparison of those fractures which had occurred under known conditions might probably reveal many features of interest, and perhaps tend to afford information regarding the molecular changes incident to breakage. The Author was therefore very desirous to obtain the photographs as quickly as possible after the fracture, and regards them as an important part of his investigation. Considerable expedition was required to effect this, as it was not easy to preserve from rust and tarnish the actual fractures for any long period. It would be well if, in cases of accidental breakages of axles or tires, &c., on railways, a photograph could in each

[1] A protected thermometer in the centre of a warm test-axle used in the warm-water bath, recorded the periodical temperature of the axles for each blow.

instance be obtained of the fracture and preserved, together with a full record of the particular circumstances obtaining. Thus from a comparison in this manner of a large number of diverse fractures much useful information might be acquired of the causes of breakage. A comparison of the photographs appears generally to show a more short or crystalline cleavage in the case of the cold tests; but a rather more fibrous character is manifested by the warm-test fractures, more so perhaps in Set III. The whole of the photographed fractures are not reproduced on the plates, but only a limited number of typical ones.

The Author has noticed that an increase in the extent of the first deflection at the first blow has an influence on the after endurance of an axle, and consequently he is of opinion that in testing axles by impact the application of a number of lesser impacts is preferable to the extremely heavy test-blows required in the specifications of some railway companies. Generally during the first blow the warm axles bent, on the average, about 14 per cent. more than the cold ones in Set III, when taken in their total length, and this increased flexion of the warm axles tended to some extent to affect their total endurance; but this inequality at the commencement was afterwards apparently counterbalanced, the peculiar and gradual reduction of deflection subsequent to the first or second blow in case of the warm tests (Table IX), appearing in itself generally sufficient to induce comparatively nearly practical equality of flexion between the cold and the warm tests in each subsequent and consecutive blow up to the time of fracture. The relative difference in the extent of the deflection after the early commencement, in a series of ten axles at 100° Fahrenheit, and ten axles at 7° Fahrenheit, was only about 3 per cent. greater in the warm tests; and afterwards this difference even showed a slightly relative greater flexion in the cold tests, when compared blow for blow.

Observations were also made with a view of ascertaining the heat imparted to the centre of the axles by the force of impact; but it could not be conveniently estimated in these experiments, apparently owing to its rapid dispersion throughout the forging.

General Recapitulation and Remarks.

An examination of the summary Tables affords some tangible results. It would perhaps, however, be unwise, in the present incomplete experimental stage of the temperature-impact question, to draw other than limited general conclusions from the indications

here afforded; and further experimental observations would be desirable, especially with regard to such higher temperature tests as those of Sets I and II. The behaviour under concussion of locomotive crank- and tender-axles, railway couplings, and other ironwork, &c., under different conditions of temperature, should likewise be studied. It would also be advantageous to observe, in a similar manner, the effects of temperature on axles, &c., which have been running and have undergone the fatigue of actual work for varied and known periods.

First.—The comparative results of the tests, Set I, on axles at the higher temperature of 212° Fahrenheit, compared with axles of this set tested at 7° Fahrenheit, will be seen on reference to the Tables, which indicate an average increase of endurance under impact in these warm tests approaching 235 per cent.; and *vice versâ*, a consequent reduced ultimate resistance in the cold tests compared with the warm ones. The ultimate flexibility, under continued impact, judging from the total deflections, at the higher temperature appears to be about 240 per cent. in excess of that at the lower one.

Secondly.—The result of the tests, Set II (in which the axles were submitted to the heavier trial of 1 ton falling 15 feet), at the temperature of 120° Fahrenheit, compared with results at 7° Fahrenheit, show an average increase of ultimate endurance of impact in favour of these warm tests of near 120 per cent., and the reverse with the cold tests. The ultimate flexibility, under repeated impact, estimated from the total deflections, in this set is about 85 per cent. in favour of the higher temperature.

Thirdly.—The summary Tables VIII and IX, show that an average total mean force of 261·96 tons was required to effect the destruction of the axles in the cold tests of Set III, and an average total mean force of 374·52 tons, to accomplish the same effect in the warm tests (100° Fahrenheit) of the same set, but under otherwise similar conditions. This comparison, therefore, of the relative strength of the axles in the warm tests (100° Fahrenheit) and the cold tests (7° Fahrenheit) gives a general average increase of ultimate resisting power in favour of the former of about 43 per cent., and a consequent similar decrease of strength in the cold tests under the conditions recorded. The ultimate flexibility under impact, taken from the total deflections in this instance, was near 31 per cent. greater in the warm than in the cold tests. The half-axles, tested respectively warm and cold in each set, confirmed the general principle.

The experiments should perhaps be regarded as of a tentative

character. The summary of the results in Sets I, II and III, however, appear generally to indicate that the ultimate power of resistance to continued heavy impact of railway axles proportionately increases with an increase of temperature within the range of the present experiments; and *vice versâ*, their power of resistance to continued heavy impact diminishes with reduced temperature. Owing to the comparatively limited number of observations, more especially in Sets I and II, the percentage results should not be regarded as specific or absolute data, but only as affording general indications. The Author had not, however, an opportunity of further extending the inquiry.

The tests at 212° Fahrenheit were purposely made to approximate to the conditions obtaining in an axle which may have become heated by accidental friction at the journals. Heating under such circumstances has occasionally been known to occur to such an extent that the journals have become nearly red-hot, setting fire to the grease-box, and even melting the brasses. Experiments relating to journal friction and train-resistance, by Mr. A. M. Wellington, demonstrate that journals frequently, even in ordinary running, arrive at a temperature of from 120° to 150° Fahrenheit.[1] In the case of overheated journals, an element of danger may arise from the peculiar modification of tensile-strength and ductility in iron or steel, recently noticed by Mr. E. Cornut, who observed that a change for weakness occurs in iron and steel at a certain temperature, as indicated by the great reduction of ductility assumed by iron and steel from about 572° to 662° Fahrenheit.[2] Furthermore, it is obvious that in practical work an axle may be exposed to disintegrating effects, arising from a considerable divergence of temperature in its various parts. Thus it is possible, during the rush of a train at 60 miles per hour through a keen frost air, for the exposed centre of the axle to be at a low temperature, whereas the two journals and adjacent parts may be kept warm, or even hot; so that in the same axle there would be a manifest want of uniformity in the relative power of resistance to sudden impact between the middle and the ends. That this difference of resisting-power at different temperatures is not trifling, the experiments of the present Paper indicate. Moreover, these divergences of temperature in the same forging tend to produce internal thermo-currents, also exerting, to

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[1] Minutes of Proceedings Inst. C.E., vol. lxxxv. p. 376. "Recent Researches in Friction." By John Goodman, Stud. Inst. C.E.

[2] *Iron*, May 1st, 1885.

some extent, disintegrating influences. A comparison between the deflection or permanent set of each axle, after the first blow in the hot and the cold tests, in each case will be seen on reference to Tables VI to X (pp. 363 to 369), on which a summary of the total average deflection results is also recorded. On referring to the more detailed records in the Tables, it will be noticed that a considerable reduction occurred in the extent of the deflections after the first blow in the case of all the warm tests, from which it would appear as though the effect of continued impact at these temperatures was to partially harden, or perhaps render the iron rather more crystalline and brittle, and thus produce an apparent reduction of flexibility. The Author has further observed this during testing at an ordinary temperature, though to a more modified extent, and with exceptions; but as no practical variation or reduction of deflection of this character was noticed in the cold tests, it may be inferred that the metal at low temperatures was probably already so far crystallized by the intense cold as to be not appreciably affected in this respect by continued impact, though perhaps it was influenced in a much less degree.

Repeated shocks, therefore, seem permanently to reduce the flexibility of railway axles. The Author has, in other experiments, demonstrated that repeated concussion, applied to an axle, not only reduces its flexibility at ordinary temperatures, but also effects a modification of the tensile-strength of the iron.[1]

An examination of some of the Tables shows that uniformity of results did not altogether prevail; the behaviour of some of these exceptions appeared abnormal and peculiar. To further investigate this matter, the two halves of each axle which behaved abnormally under impact in the cold tests were turned down to 4½ inches diameter throughout, and again tested, the one half at a low temperature and the other at a higher temperature, but otherwise under similar conditions. The results obtained are recorded in the Tables, and some axles of Set I, of very exceptional behaviour, in Table X in the Appendix, and in every such instance these exceptional axles subsequently afforded results confirmatory of the general rule. The deviations from uniformity, which at first appeared like exceptions to a general principle, and consequently not easy of explanation, were doubtless due to some molecular difference in the material itself. The manner in which the falling weight would produce marks of indentation and contortion, after the first blow, from the true

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[1] Society of Engineers. Transactions for 1879, p. 167.

circular form of the axles, may possibly also have contributed to the variation in some of the results, as these could not be entirely due to irregularity of manufacture.

All who are acquainted practically with metallurgical processes are aware of the difficulty of obtaining exact uniformity in the nature of any two forgings of iron or steel, though each may have passed through precisely the same treatment in manipulation.

Having examined the variation in the resisting power of railway axles, arising from difference of temperature, the next investigation should be in the direction of ascertaining, if possible, the nature of the molecular changes which apparently result from the diversity of temperatures. The extent of these effects may be seen on comparing the great difference between the resisting power of the axles at 100° Fahrenheit and that manifested at 7° Fahrenheit. The results obtained indicate that the alteration in the properties of the metal cannot be an inconsiderable one. The change of molecular structure incident to the relative expansion and contraction of the metal at the various temperatures, necessarily exerts its influence, though in outward extent not comparable with the relative endurance of the axle.

In the course of other experiments by the Author, observations have been taken with great care on the relative dilatation of an axle at the temperatures of 0° Fahrenheit, 100° Fahrenheit, 212° Fahrenheit, 392° Fahrenheit, and 572° Fahrenheit. Table V contains some extracts from the average results, of ten carefully-repeated observations at each temperature, made with an extremely delicate micrometer vernier gauge.

TABLE V.—LINEAR DILATATION by HEAT of BEST BEST SCRAP IRON RAILWAY CARRIAGE AXLES.

1000 parts at 32° F. become at	0° F.	100° F.	212° F.	392° F.	572° F.
..	999·768	1000·713	1001·322	1002·701	1003·650

It was noticed that the expansion at 100° Fahrenheit amounted to 0·094 per cent. of the total expansion from zero, and it will be further observed, on reference to the experiments in Tables VIII and IX, that the average reduction of ultimate resistance under impact at the low temperatures was about 43 per cent., compared with that at the higher temperature of 100° Fahrenheit, and the average reduction of total deflection at the low temperature was about 31 per cent. compared with the total deflection during the higher temperature.

These appear to be some of the chief external features of the molecular changes. The comparatively small difference of outward structural alteration obtaining between the high and low temperatures does not correspond with the relative behaviour of the metals under impact at the two temperatures, though probably a factor involved in the results. Inconsiderable though it may seem, this, together with the varying extent of the deflections, appears to be the perceptible external measurement of internal change. It may be presumed, however, that an effect producing only a very minute molecular deviation from its normal state may not improbably produce considerable difference in the properties of a metal. The internal changes which occurred in the metals during experiments of this nature appear, therefore, to be involved in some obscurity.

The theory of the molecular constitution of matter may afford material for hypothesis.

It may perhaps be reasonably assumed that, on the cooling of a forging, the molecules of the metal are arranged in what may be called their normal rigidity at the atmospheric temperature then obtaining. This normal point of rigidity may possibly vary according to the nature of the metal, and be some expression of its general strength and character. The effect of a further reduction of temperature would be a contraction affecting the molecules after they had thus normally arranged themselves. Sudden impact applied transversely to a forging during such a contracted condition, and at a lower temperature than its normal state of rigidity, would tend to induce internal molecular motion therein, and the same number of molecules would have consequently to vibrate under the influence of an equal, and sometimes even of a greater mean force of impact, than in the case of experiments at higher temperatures; but within an area reduced by contraction below the normal, they would presumably oscillate more rapidly, and rebound against each other with greater violence. The "mean force" imparted to an axle was greater during some of the earlier blows in each case in the cold tests (owing to the reduced flexibility at that temperature) compared with the warm ones.

The tendency of all this would be to induce earlier internal sources of disintegration, and greater liability to earlier fracture, under the influence of repeated concussion transversely applied during low temperatures. The sudden impact also acted with a certain wedge-like, or splitting-up force, and it may be presumed that contraction below the normal crystalline condition of a metal would induce varying properties therein.

TABLE VIII. *continued.* Set III.—*continued.*

Number of Blows.	COLD TESTS—*continued.* Axle No. 24. Permanent deflections taken from between Bearings in Inches.	Axle No. 24. Mean Force resulting from each concussion in Tons.	Axle No. 26. Permanent deflections taken from between Bearings in Inches.	Axle No. 26. Mean Force resulting from each concussion in Tons.	Axle No. 28. Permanent deflections taken from between Bearings in Inches.	Axle No. 28. Mean Force resulting from each concussion in Tons.	Axle No. 29. Permanent deflections taken from between Bearings in Inches.	Axle No. 29. Mean Force resulting from each concussion in Tons.	Axle No. 30. Permanent deflections taken from between Bearings in Inches.	Axle No. 30. Mean Force resulting from each concussion in Tons.	Average permanent deflections taken from between Bearings in Inches.	Average Mean Force resulting from each concussion in Tons.
1	2·625	46·71	2·500	49·00	2·500	49·00	2·500	49·00	2·750	44·64	2·6125	46·98
2	2·625	46·71	2 500	49·00	2·500	49·00	2·500	49·00	2·750	44·64	2·7778	41·53
3	2·500	49·00	2·625	46·71	2·500	49·00	2·375	51·53	2·625	46·71	2·5556	48·01
4	2·500	49·00	2·625	46·71	2·500	49·00	2·375	51·53	2·625	46·71	2·6875	46·00
5	..	..	..	..	..	..	2·375	51·53	2·250	54·33	2·5250	48·78
6	..	..	..	..	..	..	2·375	51·53	2·250	54·33	2·4000	52·03
7	..	..	..	..	..	..	2·250	54·33	..	..	2·5000	49·48
8	..	..	..	..	..	..	2·250	54·33	..	..	2·5625	48·53
9	..	..	..	..	..	..	2·375	51·53	..	..	2·6250	47·13
10	..	..	..	..	..	..	2·375	51·53	..	..	2·3750	51·53
11	..	..	..	..	..	..	2·375	51·53	..	..	2·3750	51·53
12	..	..	..	..	..	..	2·375	51·53	..	..	2·3750	51·53
Totals .	10·250	191·42	10·250	191·42	10·000	196·00	28·500	618·90	15·250	291·36	14·2750	261·96
Approximate temperature of normal rigidity . .	46° F.		54° F.		54° F.		54° F.		54° F.		...	..

In addition to the above experiments, four small hammered wrought-iron shafts $4\frac{1}{2}$ inches in diameter, 9 feet long, were tested by a weight of 1 ton falling 10 feet = an "energy" of 22,400 foot-pounds for each blow, two at a temperature of 0° F., and the other two at a temperature of 100° F. The two cold shafts endured an average total mean force of 113·37 tons previous to fracture, the warm ones required a total mean force of 194·86 tons to produce breakage.

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and that possibly bridges of all kinds and types and of all spans may be brought under one formula, in which only different constants are introduced according to the kind, the type, the range of span, and the proportion of depth to span, &c.

The formula by Professor A. J. Du Bois could be written

$$w = \frac{a}{\frac{b}{l} - 1},$$

if w_1, w_2, r and s, were assumed constant. This curve would have a vertical and a horizontal asymptote, the former being at a distance $l = b$, and the latter at a distance $w = -a$ from the zero-point of the system of co-ordinates. In fact, it is a hyperbola, as can be seen when the system of co-ordinates is moved to coincide with the asymptotes, *i.e.*, when $b - l$ is put for l, and $w - a$ for w. It fulfils the two important conditions of a true curve, viz., that it should always turn its concave side upwards, and that it should have a vertical asymptote, and there can be very little doubt that for a given simple law of dependence of the depth from the span, and for a given specification of strength, this curve will give good results for a greater range of spans than any other simple empirical curve.

But if the depth and the stress per inch, d and s, be made optional, and be introduced into the formula, as done by Professor Du Bois; or, going further, if the width of the bridge be made optional, the empirical is abandoned and the scientific field of research entered upon, so far as it was defined at the outset of this Paper. The simplicity of the formula will here depend upon the degree of inaccuracy allowed. Considerable allowance in this respect has been already made in the formula by the Author,[1] and if the expressions for wind-structure and secondary bracing were taken out for separate calculation, that formula would be very little longer than Professor Du Bois' formula; but in some respects, especially in the expression for the weight per lineal foot of the web of the main girders (C d), he has gone a good deal farther in the process of simplification at the expense of accuracy. That expression would be right only if the proportion $\frac{l}{d}$ were given by a special and, moreover, a complicated law, as it would be wrong if $\frac{l}{d}$ were either constant or optional; but if the depth d must

[1] Minutes of Proceedings Inst. C.E. vol. lxiv. p. 258.

be so distinctly defined in order to suit the formula, and if, therefore, it is no longer optional, the question arises, whether the formula would not be better without it. Mr. Pegram has already disposed of the introduction of the panel length p into the formula by stating that it will not materially affect the total weight; he might have added that the formula would also be better without p. In the expressions for the weight of the wind-bracing $\frac{l}{2} + \frac{1,600}{l}$, the effect of the wind-pressure with regard to the main girders seems to be excluded. As it stands it has the peculiarity of giving equal results, for example, for $l = 40$, and $l = 80$; $l = 20$, and $l = 160$; $l = 0$, and $l = \infty$.

(*Students' Paper No. 211.*)

"Locomotive Engine- and Carriage-Sheds as used on the Caledonian Railway."[1]

By Gilbert Macintyre Hunter, Stud. Inst. C.E.

(Abstract.)

In this Paper the Author gives some notes on the design, construction and cost of two locomotive-engine sheds and one carriage-shed on the Caledonian Railway, upon which he has been engaged, and which compare favourably with respect to design and cost with any other kind of shed.

The Hamilton engine-shed is of the rectangular type, and is situated north-west of Hamilton West (or Barracks) Station. It has an area of 6,000 square yards, comprises five spans of 28 feet each supported on cast-iron columns spaced 12 feet apart longitudinally, and accommodates sixty tender-engines. The roof is ridge and furrow of the ordinary Kingpost truss type with grooved ventilators; the glazing is Pennycook's Patent, 8 feet broad. There are two roads under each span. The greater part of the structure is of wood. Cast-iron columns form the framing of the side walls, which are covered with overlap boarding. On the north side the brick wall of the repairing-shop completes the shed. The roofing is of full-sized Ballachulish slates.

The engine-pits are 2 feet 7 inches deep, 3 feet 10 inches wide, and extend the full length of the roads. The rails are bull-headed, supported on longitudinal sleepers, and weigh 80 lbs. per yard, the chairs being 35 lbs. each, and this type of permanent-way is used in all the Company's sheds.

Five cross-drains from each side lead into a main 15-inch fireclay pipe-drain through the centre of the shed, the former having connections with the columns, which are also rain-conductors, the cesspools and hydrant-boxes. A 9-inch pipe-drain round the four sides of the shed joins the main drain in front, which discharges into the Wellshaw Burn.

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[1] This Paper was read at a Meeting of the Students on the 9th of April, 1886.

The workshop and offices are on the north side of the shed. The machine-shop and smithy are each 40 feet by 33 feet, and the repairing-shop is 130 feet long, all opening into the shed. An engine needing repairs that require more than a day to execute is removed at once to the repairing-shop, otherwise it is repaired in its berth.

In the yard, the roads and cross-over roads are so arranged that an engine can easily come from the main line to coal and water, or to the turntable, or pass into any of the shed roads. The switches in all the yards are controlled by tumbling levers. The turn-table is of Messrs. Cowan, Sheldon & Co.'s standard pattern.

The coaling-shed, with water-tank above, is 65 feet long by 37 feet wide, with one coal-road through the centre, and one engine-road on each side. The tank is 9 feet deep, and contains to overflow-level 124,000 gallons. There is also a small water-tank and a water-column in the yard. The coaling and watering of four engines can be performed at one time. The coaling-platforms, which are 10 feet 10 inches broad, are covered with $\frac{3}{8}$-inch iron plates. The platform is 11 feet from engine-rail level, and 3 feet 4 inches from wagon-rail level; the bottom of the tank is 25 feet from engine-rail level. The tumbling-buckets are 4 feet long, 2 feet 10 inches wide, and 2 feet deep. The coal-tips are framed of wrought-iron and oak beams. Three of the joists of the platform are projected from the wall, planked, and covered with plate-iron, and to this plate the tip is hinged. The hinged parts are suspended over cast-iron pulleys by two link-cable chains with balance-weights, and when out of use can be doubled up against iron stops. The coaling of the engines is done by contract; the foreman is paid 2·25*d.* per ton, and he employs seven assistants during the summer, and six in winter. Each man turns out about 32 tons per day. The tank rests on fifteen wrought-iron web-girders, one under each plate joint. It is formed of cast-iron plates $\frac{5}{8}$-inch thick and 4 feet square; the vertical tiers of plates are tied to the bottom plates, the first tier to the third bottom plate, and the top tier to the fourth bottom plate throughout. The inlet-pipe is 5 inches in diameter, and is fitted with an equilibrium ball-valve: the outlet to engines is a 6-inch pipe fitted with a cone-valve. The outlet pipe to the water-column is 8 inches in diameter, and the overflow pipe 6 inches. The depth of water in the tank is shown by a balance-weight water-gauge. There is a drop-pit for ashes on each side of the wagon-road leading to the coaling-shed.

The sandhouse is 29 feet long and 24 feet broad. One half of

the house is reserved for wet sand. The drying kiln, which in those parts in contact with flame is built of firebrick in fireclay, has two furnaces, the fire-grate area of each being 21·77 square feet. The floor of the kiln has an area of 81 square feet, and 2·25 cubic yards of sand can be dried in twelve hours; the sand is then sifted through inclined screens, one screen on each side of the floor, and the coarse sand passes through openings in the wall to the outside of the house. The floor of the kiln is formed of two cast-iron plates 9 feet long, 4 feet 6 inches broad, and 1 inch thick. The consumption of coal is 1·43 ton per day, including the amount required to kindle the engines. It takes an hour-and-a-half to put an engine under steam if it has been in use the day previous; if not, it takes two hours and-a-half.

Water is supplied from the Corporation of Hamilton main through a 6-inch cast-iron pipe, and the shed is fitted with valve-hydrants. Gas is brought from the Corporation main to a meter in the weigh-house on the loading-bank.

Engine-cleaners, before they are allowed to move an engine, must be qualified, and pass the locomotive superintendent; they are then termed "engine-turners." When an engine comes into the yard to be berthed, the driver leaves it over the drop-pit, where it is taken in charge by two turners, who reverse it, coal, water, drop fire, fill the sand-boxes, and run it into its berth. The cleaners then perform their part of the work, and the engine remains till morning, when the turners kindle the fire, raise the steam, and hand it over to the driver. Four passenger and fifty-one mineral engines are berthed in this shed.

The Greenock engine-shed, which also is of the rectangular type, is immediately west of Bogston Station. It has an area of 3,220 square yards, and can accommodate thirty large tender-engines. The roof has a pitch of 1 to 2 on one side, and 2 to 1 on the other. It is transverse to the engine-roads, and is carried on wooden beams supported by cast-iron columns which also form rain-conductors, and which are 26 feet $10\frac{1}{4}$ inches apart, with spandrel brackets on each side. There are five bays in the shed, with two engine-roads in each bay. Immediately over the pits, at a height of 12 feet 3 inches, wooden inverted troughs, 2 feet $7\frac{3}{4}$ inches wide, convey the smoke from the engines to small chimneys in the apex of the bays. The troughs are coated with asbestos paint, and the transverse beam is protected by galvanized iron plate. The roof is glazed on the steep side in lengths of 10 feet 9 inches; the intermediate spaces over the smoke-troughs

are covered with tapered overlap boarding, and the flat side with full-sized Welsh slates. Douglas Frazer and Son's glazing is used. It is simple, cheap, and the light is thrown on each side of the engine, and is not obstructed by the smoke-troughs.

The engine-pits are 2 feet 6 inches deep and 3 feet 9 inches wide, convex at the bottom, with a flat channel on each side, having a fall each way to bell-traps 43 feet apart in each pit. The flooring of the shed and bottom of the pits is brick-on-edge. A 6-inch fireclay pipe receives the drainage from 4-inch pipe-drains that lead from the columns, hydrant-boxes and rain-conductors in the walls. The drainage is to the centre of the shed, where a transverse 12-inch pipe-drain is connected with a cesspool at the south side. An overflow-pipe from the tank joins one from the turntable, and also leads into this cesspool, from whence there is a 15-inch pipe-drain to the Craigie Burn. The repairing-shop and smithy are across the south side, covered by an ordinary Kingpost truss roof of 26 feet 3 inches span, while the bothy, office and store are protected by extensions of the main shed roof. The repairing-shop is 99 feet long by 27 feet wide, with 30-ton sheers over the road. An 8-inch fireclay pipe is built into the wall of the store 9 feet from the floor-level, so that oil can be pumped from a wagon standing on the ingoing road into the cistern in the store. Repairs to an engine of a slight nature are done in its berth; if they will occupy more than a day the engine is removed to the repairing-shop; but repairs of a serious nature are done in the workshops at St. Rollox, Glasgow.

The roads are all so arranged as to lead the engines from the main line to the turntable, water-tank, or coaling-shed, or to any of the ten engine-roads in the shed.

The foundation of the turn-table is a bed of concrete, 11 feet square, and 4 feet 6 inches thick, on which are two courses of freestone, and finally a granite bearing-block, 6 feet square, and 1 foot 6 inches deep. The circular wall under the race is of brick-work 3 feet 10 inches thick, reduced to 1 foot 6 inches above the race. The latter is of wrought-iron bridge-section. The main girders of the turn-table are of the riveted plate type. The centre piece has four arms bolted to the main girders, and is supported by a cast-iron cone bearing on the granite block. A Siemens cast-steel pin fixed into the top cap, and turning in a convex cast-steel washer in the cast-iron cone greatly reduces the friction. The ends of the table are carried round the race on four cast-iron wheels with steel axles. The radius of the race is 23 feet 8 inches. The table is double locked at both ends by a hand lever; the

locking bolt has a travel of $5\frac{1}{4}$ inches. One man can easily turn the table when loaded with one of the Company's heaviest engines giving a load on the table of 30·46 cwt. per lineal foot.

The water-tank is 53 feet long, 17 feet wide, and 9 feet deep. containing to overflow-level 42,229 gallons. Underneath the tank there is a meter-room and two stores, of which the outside walls are of masonry 2 feet thick. The tank is formed of cast-iron plates 4 feet square, with inside flanges, cross-feathers and rust-joints. It is placed on ten cast-iron beams, and is further supported by the two partition walls between the meter-room and the stores. Transversely it is diagonally braced by 1-inch tie-rods, one end of which is fixed by a bolt, the other by a gib and cotter; there are also horizontal tie-rods from each plate immediately under the joint. The inlet-pipe is 4 inches in diameter, fitted with an equilibrium ball-valve; the outlet to the engine is an 8-inch pipe fitted with a brass ground valve, provided with an air-pipe of block tin. The outlet-pipe to the water-column is 8 inches in diameter; there is also an overflow-pipe 6 inches in diameter. From the fire in the meter-room a 9-inch pipe carried up through the tank conducts the smoke, and is a protection against frost. The main pipes are arranged so that the water can be shut off from the tank, and pass direct to the shed and water column.

The coaling-shed is 70 feet long, 28 feet 6 inches wide, 11 feet 4 inches from engine-rail level to platform level, or 3 feet 4 inches from wagon-rail level to platform level. The wagon-road can accommodate fourteen ordinary coal wagons. The shed is framed of 8-inch square posts, with intermediates and wind-ties, covered with over-lap boarding to the underside of the platform level. The roof is of the ordinary type, slated with West Highland full-sized slates. Daylight is admitted through $\frac{1}{4}$-inch rough plate-glass in common astragals. The planking of the platform is covered with $\frac{3}{8}$-inch malleable-iron plates. There are two of the Company's standard tips arranged as at Hamilton. Three men are employed coaling engines who together turn out 60 tons per twenty-four hours, being paid at the rate of 1·9*d*. per ton.

Sand drying is carried out in a reverberatory furnace 17 feet 3 inches long, 10 feet 3 inches wide, 8 feet high from the ground line, 3 feet 2 inches being below the ground. The kiln is built of firebrick in fireclay above the ground line, below that, of common brick in Arden lime. It is bound by cast-iron straps, held together both at top and bottom by tie-rods passing through the kiln. The furnace has a firegrate area of 13·75 square feet, the floor of the kiln an area of 120 square feet, which latter contains 13·3

cubic yards of sand. This quantity requires three days drying with a consumption of 30 cwt. of coal. The flame before escaping at the chimney travels 41 feet. The floor is formed of cast-iron plates with stiffeners and expansion-joints. There are four shoots, two on each side, from which the sand runs out when the shoot is open on to inclined frame screens of ¼-inch mesh wire cloth. The sand drops into a trough 3 feet 4 inches wide the full length of the kiln, containing 3 cubic yards, and from this trough the turners charge the engine boxes.

There is an 8-inch cast-iron main from the Greenock Water Trust's main in Gibbshill]Road to the water-tank, with a 6-inch branch to a Kennedy's water-meter, and other branches leading to wheel-valve hydrants in the shed. The outlet from the tank to the column is an 8-inch pipe, while a 6-inch branch from the main joins it, and leads to the water-column, so that the column can be supplied direct from the main.

The gas is brought by a 2-inch cast-iron pipe from the Gibbshill Road to the meter-room under the tank, and thence across the yard to the coal-shed, then to the shed at the store.

Five passenger, nine goods, and eight shunting engines occupy eight of the ten roads. The berths are so arranged that each engine enters the shed, and passes out without necessitating a shunt of any of the other engines. All the engines enter the shed from the east side and leave by the west side.

Gushetfaulds carriage-shed is situated close to Gushetfaulds Station, a suburban station in Glasgow on the main line. It is 387 feet long, varies in breadth from 84 to 250 feet, and covers an area of 7,617 square yards, capable of accommodating one hundred and forty-one carriages. There are six bays of 40 feet 4½ inches span, with three roads in each bay, numbered from the main line on the south-west side, having a total length of 5,382 feet. In the centre of the shed there are six roads, each 387 feet long; three roads on each side 291 feet long, and the remaining six outside roads 219 feet long. Twenty-four men are employed in the shed. The roof is of the ridge and furrow type, both wrought- and cast-iron being used. The principals are of 40 feet 4½ inches span, 6 feet apart. Between each two bays there is a line of cast-iron columns 24 feet apart, connected longitudinally by a cast-iron trough gutter, which also serves as a girder, and to lugs on this gutter the principals or couples of the roof are severally connected. There are cast-iron shoes on the division walls in which the couples are fixed. There are no purlins in the roof, except where daylight is admitted.

The sheeting is laid on chamfered runners bolted to each iron principal. The latter are tied together by diagonal wind-braces. The roof is covered with full-sized slates and rough-ribbed glass. Three different systems of glazing are employed. The centre bay is glazed by the Pennycook system, while two side bays are respectively glazed by Rendle's acme system, and Mackenzie's system. In none of these systems is putty required.

Footways, or wooden platforms, 2 feet wide on top, of 3-inch planking, 2 feet 6 inches from rail-level, supported every 6 feet by trestles, extend between each carriage-road the full length of the road, and admit easy access to the carriages. When the carriages are more generally fitted with gas the amount of work in a shed like this will be much diminished. At present three men are constantly employed cleaning lamps, while a separate staff is occupied substituting clean lamps for dirty ones. The flooring consists of brick on edge set on shivers; the 5-feet ways are convex, the 8-feet concave. Every 48 feet in the 5-feet ways there is a cesspool; and running down the centre of each bay there is a 15-inch fireclay pipe-drain connected with the cesspools and columns. The main drains all join together, and lead into a brick sewer, connecting with the Glasgow Corporation sewer.

A 3-inch pipe from the Glasgow Corporation water-main in Cathcart Road enters the front of the centre bay of the shed, and is continued along each of the centre walls with transverse branches each way, provided with stop valves, and several screw-down taps in each road. The shed is lighted with double-light hanging brackets from each principal of the roof over the footways, and there are also lights on the division walls and columns.

From roads Nos. 9 and 10 the carriages are charged with Pintsch's gas from eleven stop-cocks 34 feet apart. The apparatus for making the gas is at Bridge Street Junction, fully ½ mile distant, and from there to Bridge Street Station, and thence to Central Station, pipes are laid so that trains can be charged while standing at both stations. About 80 per cent. of the carriages in this shed are fitted for burning gas, mostly by Pintsch's and Pope's systems, and a very few by Laidlaw's system. Composite carriages with four lights have one cistern fixed under the frame of the carriage, 10 feet long, containing gas compressed to 12 atmospheres, sufficient for seventy-two hours' consumption. The majority of the carriages, however, have two cisterns 5 feet long, 18 inches in diameter, with a pressure of eight atmospheres, equal to forty-eight hours' burning.

The lamp-room, offices, bothy, &c., are in a building close to the shed. The former contains three hundred lamps, and a saddle-boiler for supplying hot water to wash the carriages.

By means of telephonic communication between Central Station and Larkfield Signal Cabin, special orders are given to the Superintendent.

The arrangement of the roads in the yard admits of a free and speedy marshalling of a train, also ready access to the turn-table. In conclusion the Author describes the modes of berthing and marshalling trains at Gushetfaulds Junction.

The Author wishes to tender his warmest thanks to Mr. Robert Dundas, M. Inst. C.E., for his kind permission to give this Paper; and also to those Railway Engineers and Students who aided him in the preparation of Appendix II.

[APPENDIXES.

APPENDIXES.

APPENDIX I.—Cost of the Sheds, not including the Permanent Way.

Hamilton Engine-Shed.

	£	s.	d.
Total cost per engine, with all appurtenances . . .	223	1	8
„ „ without „ . . .	166	10	8
„ „ for gas and water	11	5	0

Details.

	s.	d.	
Main shed complete	10	$5\frac{1}{4}$	per square foot.
Brickwork	3	$6\frac{1}{2}$	„ „
Main shed (wood and brick)	0	$1\frac{9}{16}$	per cubic foot.
Repairing shop (brick)	0	$1\frac{1}{2}$	„ „
Glazing (Pennycook's patent)	1	$3\frac{1}{2}$	per square foot.
Coaling shed and tank (stone and iron). . .	0	$6\frac{5}{16}$	per cubic foot.
Tank (cast-iron), exclusive of valves . . .	0	$7\frac{1}{4}$	„ „
Sand furnace, &c.	0	$2\frac{3}{4}$	„ „

Greenock Engine-Shed.

	£	s.	d.
Total cost per engine, with all appurtenances	308	7	4
„ „ without „ . . .	197	16	0
„ „ for gas and water	12	4	8

Details.

	s.	d.	
Main shed complete	12	$3\frac{1}{2}$	per square foot.
Brickwork	2	$2\frac{1}{2}$	„ „
Glazing (Frazer's patent)	0	$7\frac{3}{4}$	„ „
Water-tank (stone and iron)	0	$2\frac{1}{4}$	per cubic foot.
Coaling shed (wood)	0	$2\frac{3}{4}$	„ „
Kindling and sand-drying furnace	0	$1\frac{1}{4}$	„ „

Gushetfaulds Carriage-Shed.

Total cost per carriage . . . . £66.

Details.

Glazing—

(1) Pennycook's patent . . . . }
(2) Rendle's "acme" . . . . } 1s. per square foot.
(3) Mackenzie's patent . . . . }

The cost here given, being the contract price, is considerably under the actual cost of each system, but owing to each sub-contractor being desirous of having his system applied, an arrangement was made between the contractor and sub-contractors to supply the glazing at the contract price.

APPENDIX II.—Cost of Sheds on other Railways.

Engine-Sheds.

Name of Railway.	Kind of Shed.	Where situated.	Number of Tender-Engines.	Cost per Engine. £. s.	Remarks.
Lancashire and Yorkshire	Rectangular	Mirfield	32	263 0	Weaving-shed roof, concrete pits, stone built, including workshops, gas and water fittings, &c.
Do.	Do.	Lower Darwen	32	299 0	Ridge-and-furrow roof, brick built, including workshops, gas and water fittings.
Do.	Do.	Lostock Hall	32	302 0	Do. do.
Great Northern of Ireland	Do.	Newry	4	321 10	Iron roof, with mess room, sand store, office, store and workshop.
Do.	Do.	Dublin	20	190 0	Iron roof, brick built, with cast-iron water tank on roof containing 55,000 gallons.
London, Brighton and South Coast	Do.	New Cross	20 tender-engines or 32 tank-engines	387 0	Iron roof, brick built, gas and water fittings.
Do.	Circular	Battersea[1]	12 tender-engines 42 tank-engines 8 "A" class engines 62 Total	251 0	Do. do.
Do.	Radial	Horsham	10	355 0	Iron roof, brick built, office and store, gas and water fittings.
North British	Rectangular	Cowlairs	67	208 2	Iron roof, stone built, including gas and water fittings.
Do.	Do.	Parkhead	12	275 0	Timber couples, stone built, including gas and water fittings and foreman's office.
Do.	Circular	St. Margaret's	16	402 15	Iron roof, stone built, including gas and water fittings.

[1] There are two circular sheds at Battersea, for which the contract was let in one, and the cost of each cannot be satisfactorily given. This of course increases the cost per engine, compared with a shed of equal accommodation.

CARRIAGE-SHEDS.

Name of Railway.	Kind of Shed.	Where situated.	Number of Carriages.	Cost per Carriage. £. s.	Remarks.
Lancashire and Yorkshire	Square	Newton Heath	130	132 5	Brick built, slated and glazed, gas and water fittings, heating apparatus, paving upon concrete with wood blocks, brick built pits.
Do.	Rectangular	Horwich	46	34 11	Corrugated iron shed, without any fittings, simply a storage-shed for carriages during the winter.
Great Northern of Ireland	Do.	Dundalk	30	93 8	Brick built, ridge-and-furrow roof.
North British	Do.	Cowlairs	200	113 8	Stone built, ridge-and-furrow roof iron, including gas and water fittings.

(*Paper No. 2207.*)

"On the Manufacture of Rolled Joists in Belgium."[1]

By J. Wolters.

(Translated and Abstracted by W. Silver Hall, Assoc. M. Inst. C.E.)

The manufacture of rolled joists in Belgium now amounts to some 120,000 tons per annum. The Author takes, as a typical instance, an establishment with two blast-furnaces, each capable of producing 100 tons of iron per day, and a rolling-mill able to turn out an average of 2,700 tons of joists per month.

Quality of Iron.—For joists, and indeed for every class of rolled iron of bold profile, the pig must be soft enough to give an iron that will elongate freely without cracking or tearing under the unequal strains put upon it by the various parts of the grooves in the rolls.

The "minettes," or oolitic iron ore of the Grand Duchy of Luxembourg, containing in its raw state from 0·53 to 0·90 per cent. of phosphorus, but only a trace, some 0·03 per cent. of sulphur, is almost exclusively used, with a dose, amounting to from 25 to 30 per cent. of the total charge, of "mixed slag," composed of slags from the puddling and re-heating furnaces in about equal proportions, their composition, as ascertained by repeated analyses, being as follows:—

—	Puddling Slag.	Reheating Slag.
Silica	8·60 to 14·20 per cent.	20·20 to 27·80 per cent.
Sulphur	0·10 „ 0·62 „	0·09 „ 0·93 „
Phosphorus	3·15 „ 8·07 „	1·00 „ 2·87 „

If this proportion is exceeded, the pig will contain an excess of sulphur and phosphorus. Analyses of the pig produced

[1] From a paper in the Annuaire de l'Association des Ingénieurs sortis de l'École de Liége, 1886, vol. v. p. 123.

with various proportions of mixed slag give the following results:—

Percentage of Mixed Slag.	None.	20 to 25.	25.	30 to 35.	45.
Silicon, per cent.	0·50	0·19	0·27	0·23	0·23
Sulphur „	0·28	0·59	0·60	0·71	0·77
Phosphorus „	1·54	2·12	2·24	2·25	2·63

So far as regards the behaviour of the iron in the rolls, without regard to its quality when finished, (and a breaking strain of 20 tons per square inch is as much as is usually required in specifications,) an excess of phosphorus is not such a serious defect as an excess of sulphur. The following Table shows the results obtained from the analysis of three samples of pig, suitable for producing joists of ordinary quality:—

——		Pig.	Puddled Bars.	Finished Iron.
		Per cent.	Per cent.	Per cent.
No. 1	Silicon	0·21	0·20	0·17
	Sulphur	0·82	0·58	0·07
	Phosphorus	1·79	0·97	0·78
No. 2	Silicon	..	0·08	trace
	Sulphur	0·53	0·10	0·07
	Phosphorus	2·40	1·10	0·36
No. 3	Silicon	0·35	..	0·14
	Sulphur	0·53	0·04	0·02
	Phosphorus	2·04	0·34	0·31

Some makers advocate a proportion of 35 or even 40 per cent. of mixed slag to 65 or 60 per cent. of ore, provided that the cinder is so dosed as to contain sensibly as much lime as silica; but the Author is of opinion that this will result in increased labour and loss in puddling, and will give an inferior quality of iron, with an increased waste at the shingling hammer and blooming rolls.

Coke.—The coke ordinarily used seldom contains more than 0·50 per cent. of sulphur, that used in the Charleroi district being somewhat superior in this respect to the quality employed at Liége. Out of numerous types of coke ovens in use in Belgium, the Appolt and the Coppée ovens are most generally employed. For various reasons the Author gives the preference to the latter, from the working of which he deduces the following figures:—

	Francs.
Coal consumed	10·84
Total labour	0·61
Engine coal, stores, &c.	0·12
Establishment charges	0·15
Interest, bank charges, &c.	0·20
Sinking fund for repairs and replacement	0·34
Nett cost of coke per tonne	12·26

(9*s.* 10½*d.* per ton.)

Blast-Furnaces.—These are two in number, each capable of turning out 100 tons of pig per day. Their principal dimensions are:—Total height, 65 feet 7 inches; diameter at bosh, 16 feet 5 inches; diameter at throat, 13 feet 1 inch; diameter at bottom of hearth, 6 feet 7 inches. The blast is raised to a high temperature, the Cowper-Siemens stoves being those usually adopted in Belgium for this purpose. With coke at the price given in the Table above, and a mixture of 75 per cent. ore to 25 per cent. slag, which may be expected to yield 37 per cent. of pig, the nett cost will be as follows, the price of the raw materials including delivery at the furnace:—

	Francs.
Ore, 2,028 kilog. at 7·70 francs per 1,000 kilog.	15·62
Slag, 676 „ 3·75 „ „	2·54
Coke, 1,047 „ 12·26 „ „	12·84
Fettling, 325 „ 1·50 „ „	0·49
Total labour	2·57
Coal for boilers and locomotive, &c.	0·59
Establishment charges	0·47
Interest, bank charges, &c.	0·78
Sinking fund for repairs and replacement	0·33
Nett cost of pig per tonne	36·23

(29*s.* 2½*d.* per ton.)

Equipment of Rolling-Mill.—For every 1,000 tons of finished joists of average section, 1,074 tons of puddled bars (No. 1 iron) and 206 tons of fagoted bars (No. 2 iron) will be required, or 2,900 and 556 tons respectively for an output of 2,700 tons of joists per month, allowing for croppings and wasters. For the 556 tons of No. 2 bars, 683 tons of material will be required, consisting of 354 tons of crop-ends and waster-joists, 41 tons of crop-ends of No. 2 bars, and 288 tons of puddled bars.

The total quantity of puddled bars required per month will therefore be 2,900 + 288 = 3,188 tons.

As a matter of fact, no Belgian works are capable of producing

this quantity of puddled bars, even when turning out 2,700 tons of joists. Assuming that 2,400 tons are made on the works, the balance of 788 tons must be procured elsewhere. These 2,400 tons are the produce of twenty-six puddling furnaces of ordinary construction, served by three 50 cwt. shingling-hammers and two trains of blooming-rolls, dealing with the blooms from seventeen and nine puddling furnaces respectively. In case of accident or of prolonged stoppage of one train, each train ought to be able to deal with the product of the whole twenty-six furnaces, and to do this it must consist of three sets of three-high rolls, each set having the necessary grooves for roughing and finishing the hammered blooms.

The fagoted bars will be rolled on a special train of two sets of three-high rolls, and for the 556 tons required per month, a single large furnace, 11 feet 6 inches by 8 feet 3 inches, urged by a forced blast, will be sufficient.

To turn out 2,700 tons of joists per month, three trains of rolls, each driven by its own engine, will be required.

The first train will have rolls 20 inches in diameter, and their best arrangement will be in four sets of housings, the first carrying the roughing-rolls suitable for the largest possible number of sections, and the second the finishing-rolls for the section most in demand. These sets need never be disturbed, and can be worked while the third and fourth sets are being changed.

Even with a train of only three sets, the time lost in changing rolls is greatly reduced. The first set, that next to the pinions, which of course adjoin the engine, will carry the roughing-rolls for the most usual sections, say, for joists 5½ by 2 to 2¼ inches, 6¼ by 2 to 2¼ inches, and 7 by 2¼ to 2½ inches, representing probably one-third of the total joists rolled on this train; and these rolls need never be unshipped. The second set will carry the various finishing-rolls, and the third the roughing-rolls for sections not rolled by the first set, all the sets being three-high.

This train will roll the lighter sections, comprehended under the three first groups of the Belgian classification, with a height of from 3 to 8⅝ inches, a width of from 1½ to 4 inches, and a weight of from 4 to 27 lbs. per foot run, and also channel-bars weighing from 13 to 18 lbs. per foot run. For these channel-bars, and also for sections only occasionally called for, it is better not to employ three-high sets, on account of the loss of time in changing rolls; but the roughing-rolls, which will always serve for two or three, and sometimes for four or five sections, should all be three-high.

The train above described, which is capable of turning out

1,000 tons per month on the average, will be served by three furnaces with forced blast, to which further reference will be made; and there should be a fourth furnace in reserve.

The second train, like the first, will have three or four sets of three-high rolls, arranged as in the first train, two rolls only being used for the less usual sections and for channel bars; but as they will be employed on heavier sections, chiefly those of the fourth and fifth classes, with a height of from 8 to 12 inches, a width of flange of from $3\frac{1}{2}$ to $5\frac{1}{4}$ inches, and a weight of from 19 to 56 lbs. per foot run, and upon channel bars of from 30 to 40 or 43 lbs. per foot run, the rolls should be 24 inches in diameter.

This train will be served by two re-heating furnaces, with a third in reserve, and will turn out an average of 900 tons per month.

The third train, adapted for channel bars 12 inches wide, and for joists of the largest size, say, from 12 by $5\frac{1}{2}$ inches to 20 by $8\frac{1}{2}$ inches, weighing from 32 to 122 lbs. per foot run, will have three sets of rolls 28 inches in diameter. On account of the difficulty of handling the heavy piles required, this train will be only two-high, and reversible, either directly by reversing the engine, or by means of gearing. As a rule, a passage through all the rolls will be required to finish each of these heavy sections.

With two large re-heating furnaces and forced draught the monthly output will be upwards of 800 tons; with three furnaces, from 1,100 to 1,150 tons.

Puddling-Furnaces.—These are usually of the ordinary type, with a single working door. At Liége, with a flaming coal, a small hearth or "cassin" for heating the broken pig before introducing it into the puddling-hearth is frequently employed; but in the Charleroi district, where the coal is less flaming, the interposition of the cassin between the puddling-hearth and the boiler results in a serious loss of steaming power. Double hearths, with two working doors, either with or without the cassin, are decidedly more economical than single ones as regards their consumption of fuel, but the waste of iron is greater by some 3 per cent., and the quality produced is inferior. This, though not of so much consequence for joists, is a serious matter in mills employed on merchant bars.

A single hearth, with cassin, working from nine to ten charges each of 5 cwt. of pig, will turn out about 2 tons of puddled iron per day of twelve hours, the mean proportion of pig to puddled bars being as 1,149 to 1,000.

Without cassin, the proportion remains the same, but only

eight and a half to nine charges, producing about 1 ton 16¼ cwt., can be worked in the same time.

A double hearth, with cassin, working eight charges of 8¾ cwt. of pig each, will produce nearly 3 tons of puddled bars, the average proportion of pig to iron being as 1,180 to 1,000.

Without cassin, the proportion will be the same, but the output will be only 2 tons 11 cwt.

Re-heating- or Balling-Furnaces.—These are generally blown with forced blast, and the size of the hearth is from 10 feet 2 inches by 7 feet 2 inches to 14 feet 8 inches by 13 feet, according to the size of the piles. For joists of ordinary section from 10 to 12 tons of piles are heated per day of twelve hours, and for the heaviest sections from 15¾ to 17¾ tons. In some works as many as five furnaces are employed for the second train of rolls, with a total output of 68 tons per day. A great depth of grate is adopted, and it is only necessary to rake out once in the twelve hours, as compared with twice or three times with grates of ordinary proportions. Several openings for air, previously heated by passing through channels formed under the hearth, are provided near the bridge, thus ensuring a more complete combustion.

In nearly all the Belgian works the joists are rolled at a single heat.

Cost of Puddled Bars.—The following Table is based on the average working in the Charleroi district, with single puddling furnaces without cassin. In the Liége district, with a better class of fuel, allowing the puddling furnaces to be built with a cassin, the figures would be rather more favourable:—

	Francs.
Pig, 1,149 kil. at 36·23 fr. per 1,000 kil.	41·62
Coal, 1,035 „ 9·82 „ „	10·16
Total labour	8·34
Bricks, sand, oil, tallow, brasses, and other stores, deducting value of old materials	2·72
Establishment charges	0·87
Interest, bank charges, &c.	0·06
Sinking fund for repairs and replacement.	1·00
Nett cost of puddled bar per tonne	64·77

(52*s.* 2½*d.* per ton.)

Cost of Fagoted Bars (No. 2 iron).—It has already been shown that for 2,700 tons of girders 556 tons of No. 2 iron are required. These in turn require 683 tons of piles. Again, the croppings from 2,700 tons of girders amount to 354 tons, and those from 556 tons of No. 2 bars to 41 tons. The 683 tons of piles will

therefore be composed of 354 + 41 = 395 tons of croppings, worth 62·43 francs per ton, and of 288 tons of puddled bars at 64·77 francs per ton. The total nett cost will therefore be as follows:—

		Francs.
Croppings, 710 kil. at 62·43 fr. per tonne		44·33
Puddled bars, 518 „ 64·77 „		33·55
Coal, 325 „ 9·82 „		3·19
Labour		9·28
Stores, various	2·84	
Establishment charges	1·28	
Interest, bank charges, &c.	0·09	
Sinking fund for repairs and replacement	1·00	
		5·21
		95·56
Less value of croppings and wasters, 74 kil. at 62·43 fr.		4·62
Nett cost of No. 2 bars per tonne		90·94

(73s. 3½d. per ton.)

Cost of Joists.—The cost of the first and second classes of joists (Belgian classification), rolled on the 20-inch train, will be sensibly the same, and may be stated as follows:—

	Francs.
Puddled bars, 1,076 kil. at 64·77 fr. per tonne	69·69
No. 2 bars 195 „ 90·94 „	17·74
Coal, 465 „ 9·82 „	4·57
Labour	8·74
Stores, establishment, and bank charges and sinking fund (as above)	5·21
	105·95
Less croppings and wasters, 119 kil. at 62·43 fr.	7·43
Nett cost per tonne	98·52

(79s. 5d. per ton.)

The cost of the third class, rolled on the same train, will be:—

	Francs.
Puddled bars, 1,002 kil. at 64·77 fr. per tonne	64·90
No. 2 bars, 276 „ 90·94 „	25·10
Coal, 479 „ 9·82 „	4·65
Labour	8·74
Stores, &c., &c. (as above)	5·21
	108·60
Less croppings and wasters, 122 kil. at 62·43 fr.	7·62
Nett cost per tonne	100·98

(81s. 5d. per ton.)

The fourth and fifth classes are both rolled on the 24-inch train, at the following cost respectively:—

FOURTH CLASS.

				Francs.
Puddled bars,	1,062 kil.	at 64·77 fr.	per tonne	68·78
No. 2 bars,	233 „	90·94	„	21·19
Coal,	492 „	9·82	„	4·83
Labour				7·92
Store, &c., &c. (as above)				5·21
				107·93
Less croppings and wasters, 135 kil. at 62·43 fr.				8·43
Nett cost per tonne				99·50

(80s. 2½d. per ton.)

FIFTH CLASS.

				Francs.
Puddled bars,	1,079 kil.	at 64·77 fr.	per tonne	69·89
No. 2 bars,	185 „	90·94	„	16·82
Coal,	489 „	9·82	„	4·80
Labour				7·92
Stores, &c., &c. (as above)				5·21
				104·64
Less croppings and wasters, 122 kil. at 62·43 francs				7·61
Nett cost per tonne				97·03

(78s. 2½d. per ton.)

Joists of the sixth, seventh and eighth classes, and unclassed joists up to 20 inches deep, are rolled on the 28-inch train, at the following costs respectively:—

SIXTH CLASS.

				Francs.
Puddled bars,	1,079 kil.	at 64·77 fr.	per tonne	69·89
No. 2 bars,	185 „	90·94	„	16·82
Coal,	489 „	9·82	„	4·80
Labour				8·25
Stores, &c., &c. (as above)				5·21
				104·97
Less croppings and wasters, 122 kil. at 62·43 fr.				7·61
Nett cost per tonne				97·36

(78s. 6d. per ton.)

SEVENTH CLASS.

				Francs.
Puddled bars,	1,099 kil.	at 64·77 fr.	per tonne	71·18
No. 2 bars,	189	„ 90·94	„	17·19
Coal,	583	„ 9·82	„	5·73
Labour				8·25
Stores, &c., &c. (as above)				5·21
				107·56
Less croppings and wasters, 143 kil. at 62·43 fr.				8·93
Nett cost per tonne				98·63

(79*s.* 6*d.* per ton.)

EIGHTH CLASS AND UNCLASSED.

				Francs.
Puddled bars,	1,117 kil.	at 64·77 fr.	per tonne	72·35
No. 2 bars,	194	„ 90·94	„	17·64
Coal,	677	„ 9·82	„	6·65
Labour				8·25
Stores, &c., &c. (as above)				5·21
				110·10
Less croppings and wasters, 163 kil. at 62·43 fr.				10·18
Nett cost per tonne				99·92

(80*s.* 6½*d.* per ton.)

It would therefore appear that with works well laid out and favourably situated, the following prices will rule, after making ample allowance for depreciation and renewals:—

		s.	*d.*
Coke	nett cost per ton	9	10½
Pig	„	29	2¼
Puddled bars	„	52	2½
No. 2 bars	„	73	3½
Joists (average)	„	79	7½

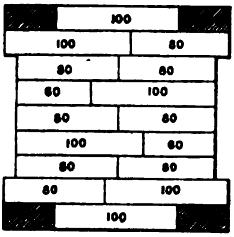
Many attempts have been made to reduce the cost by substituting puddled bars, but of a superior quality, for the No. 2 bars in the piles, but the result has not proved successful, either as regards quality or economy; and the proportions given above, ranging from about 15 to 22 per cent. of the whole pile, are as low as can be safely adopted. It may be assumed that each additional 1 per cent. of No. 2 bars in the pile will increase the nett cost of the joists by 3*d.* per ton.

The average waste of the piles in the furnace is about 12 per cent., and that from wasters and croppings, supposing some 20 inches cut off each end of the finished joist, 4·7 per cent.; but this

is to some extent affected by the lengths of the bars. For example, the comparative cost per ton of joists of the first and second classes, cut to dead lengths, is: 16 feet long, 81*s.* 3*d.*; 30 feet, 80*s.*; 50 feet, 79*s.* 6*d.*; 65 feet, 79*s.* 3*d.*

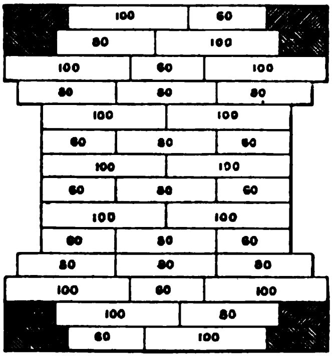
The annexed engravings give examples of piles as built for joists 7 inches by $2\frac{1}{4}$ inches by $\frac{1}{4}$ inch, weighing $10\frac{1}{2}$ lbs. per foot; 12 inches by 5 inches by $\frac{7}{16}$ inch, weighing 34 lbs. per foot; and

Fig. 1.



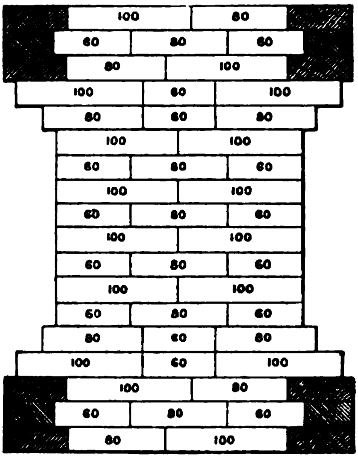
Pile for Joists.
7 in. × $2\frac{1}{4}$ in. × $\frac{1}{4}$ in.
$10\frac{1}{2}$ lbs. per foot.
Scale $\frac{1}{8}$.

Fig. 2.



Pile for Joists.
12 in. × 5 in. × $\frac{7}{16}$ inch. 34 lbs. per foot.
Scale $\frac{1}{8}$.

Fig. 3.



Pile for Joists.
16 in. × 6 in. × $\frac{1}{2}$ in. 57 lbs. per foot.
Scale $\frac{1}{8}$.

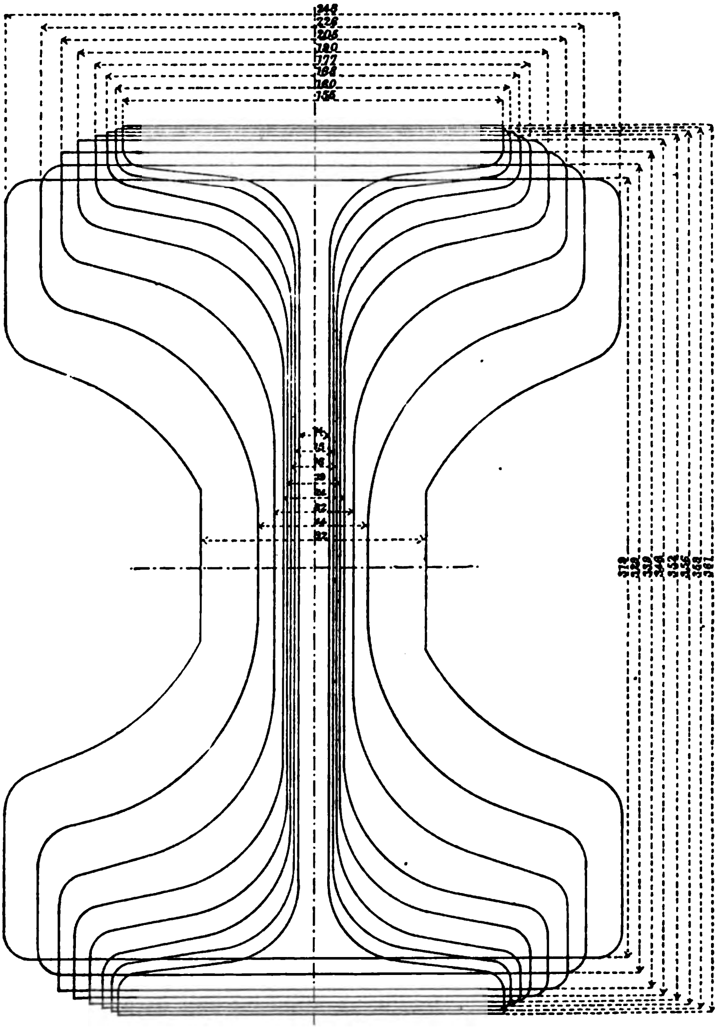
16 inches by 6 inches by $\frac{1}{2}$ inch, weighing 53 lbs. per foot; the shaded parts in each denoting the proportion and arrangement of No. 2 bars, the dimensions being given in millimetres.

An example is also given (p. 413) of the form and draught of grooves for rolling joists 14 inches by 6 inches by $\frac{1}{2}$ inch.

The Paper, which is of considerable length, contains exhaustive particulars and tables of the rates of wages, and of current and

incidental expenses in each department and at each stage of manufacture, and is illustrated by plates giving particulars of

Fig. 4.



Grooves for Rolls for Joists.
14 in. × 6 in. × ½ in. 53 lbs. per foot. Scale ½.

coke-ovens and section of blast-furnace, besides the examples of piling for various sections of joists, and of the form and draught of grooves as above given.

[Appendix.

APPENDIX.

From the very exhaustive prime-cost Tables furnished by Mr. Wolters, the following statement of the average rate of wages in Belgium at the present time has been compiled. There are, of course, a day and a night shift of twelve hours each.

		s.	d.
Coke Ovens:—			
Foreman	per day	3	4
Coke burners	„	2	4
Labourers	„	1	6
Boys	„	1	0
Engine-men at crushers and coke-drawing apparatus	„	2	1
Unloading coal-wagons	per ton	0	0$\frac{3}{4}$
Blast Furnaces:—			
Foreman (over two furnaces)	per day	3	2
Top chargers	„	2	2
Tappers and moulders	„	2 2 to 2 9	
Labourers	„	1	5
Engine-man at blowing-engine	„	2	2
„ hoists	„	2	0
Stokers, and man in charge of hot-air apparatus	„	2	2
Slag loaders	„	2	3
Unloading ore, slag, &c., from wagons	per ton	0	0$\frac{3}{4}$
„ „ „ boats	„	0	2$\frac{1}{4}$
Breaking ore	„	0	0$\frac{3}{8}$
„ slag	„	0	0$\frac{1}{8}$
„ fettling	„	0	2
Weighing pigs and loading into wagons	„	0	2
Puddling Furnaces:—			
The puddler and his under-hand are paid piece-work, at the rate of 1*s*. 11*d*. and 1*s*. 5*d*. respectively per ton of puddled bars made; or—			
Puddlers	per day	3	6
Under-hands	„	2	6
Shinglers	„	4	1
Rollers	„	2	11
Catchers	„	2	2
Hookers	„	1	2
Coachers	„	1	3
Shearers, lads, hammer-drivers, &c.	„	1	2
Roll-turners, leading-hand	„	8	0
„ under-hands	„	2 9 to 4 0	
Fitters, leading-hand	„	6	9
„ under-hands	„	2	8
Weighing-machine men	„	2	4
Engine-men	„	2	4
Boiler tenter	„	2	2

		s.	d.
Bar Mill:—			
Engine-man	per day	2	4
Heaters, leading-hand	,,	6	0
,, under-hands	,,	2	6
Rollers, leading-hand	,,	4	10
,, under-hands	,,	3	5
Roughers, leading-hand	,,	3	0
,, under-hand	,,	2	9

The wages for the lighter joist mills are intermediate between the above and the following:—

Heaviest Joist Mill:—			
Heaters, leading-hand	per day	6	6
,, under-hand	,,	2	11
Rollers, leading-hand	,,	5	4
,, under-hand	,,	3	8
Roughers, leading-hand	,,	3	4
,, under-hand	,,	3	0
Hooker	,,	2	4
Shearsman, leading-hand	,,	3	1
,, under-hand	,,	2	0

Sundry:—			
Engine-wright	,,	4	7
Smiths, carpenters, bricklayers	,,	2	8
Plate-layers	,,	2	4
Strikers or labourers to above, night watchmen, weighing-machine men, yard labourers, &c.	,,	2	0
Head ganger	,,	4	0
Assistant ganger	,,	2	5
Locomotive driver	,,	3	0
Stoker and cleaner	,,	1	9
Gate-keepers, lamp-lighters, and laboratory assistants	,,	1	7
Boy in stores	,,	1	3

OBITUARY.

WILLIAM ADAMS was born at Rhymney, on the 10th of October, 1813. After being under tuition at the Cowbridge Grammar School, he was apprenticed, in May 1828, to Mr. Charles Lloyd Hartford, managing partner of the Ebbw Vale Co., for a period of seven years, in general mining-works, and roads in connection with the mines and iron-works. Subsequently he became surveyor and assistant to his father, who was the mining-manager to the Company. In the year 1832 he surveyed and set out lines of main road to connect the Ebbw Vale Iron-works with the Brecon Canal, under the 8-mile clause of that Company's Act. In 1833, under Mr. Hodgkisson, Engineer, and Mr. Morris, Surveyor, he was engaged on a survey from the Ebbw Vale and Nantiglo works, by way of Abergavenny and Usk, to the Port of Newport, and plans were deposited in November of that year; the hill-portion of the work, a length of about 12 miles, was entrusted to him, and he assisted in preparing the plans for the whole line. In 1845, when the Welsh Midland scheme of railways was projected through South Wales, the Ebbw Vale Company being much interested in the matter, Mr. Adams took up his quarters at Tredegar, and acted under the late Mr. Joseph Gibbs, M. Inst. C.E., and Mr. Pritchard, of the Newport, Abergavenny, and Hereford Railway. At this time he was intrusted with the distribution of the engineers and surveyors over the work between Abergavenny and Merthyr, and through the hill country to Brecon. In 1853 he opened out the Brendon Hills Spathose Iron Mines, belonging to the Ebbw Vale Company, and had charge of them for some years. In 1855 he was appointed Assistant Manager of the Ebbw Vale Company's works, which office he held for ten years. In 1865 he commenced practice as a civil and mining engineer in Cardiff, soon gaining a foremost position in the profession. His opinion on all matters pertaining to coal-mining and the allied subjects was highly valued, and he acted as consulting engineer for some of the largest collieries in the district. The great demand upon his time led to his taking into partnership Mr. Theodore Vachell, Assoc. M. Inst. C.E., who had been an articled pupil of his, and had acted as his assistant for many years.

Mr. Adams took a great interest in the Free Library, and, in conjunction with Mr. E. S. Robinson, the then librarian, Mr. Bell,

the resident engineer of the Barry Dock, Mr. Peter Price, and a few others, started the now flourishing institution known as the Cardiff Naturalists' Society, of which for the first six years of its existence he filled the office of President. He may also fairly be considered the founder of the present Cardiff Museum, for when it was resolved to cede the collection of the Naturalists' Society to the Free Library, he and Professor Etheridge spent a considerable time in arranging and naming the geological collection which formerly belonged to the old Literary institution in Crockherbtown, and which, with the library, had been handed over by Lord Bute to the Free Library Committee. He also took an active part in the formation of the South Wales Institute of Engineers. At the time of his death he was Local Secretary of the Palestine-Exploration Fund, and, as an old member of St. Andrew's Church, had filled the office of Churchwarden for several years, and represented the parish at the first Llandaff Diocesan Conference.

Mr. Adams was elected an Associate of the Institution on the 1st of May 1855, and was transferred to the class of Members on the 16th March 1880. He was also a Fellow of the Geological and of several other Societies. He died on the 17th of August, 1886.

ROWLAND CHILDE, the eldest son of Joseph Childe, Mining Engineer to the Low Moor Iron Company, was born at Flockton, near Wakefield, on the 29th of April, 1826. He was educated at Elmley Grammar School. In 1842 he was articled to Mr. Henry Holt of Wakefield, who at that time was one of the foremost engineers in the West Riding. Mr. Childe was engaged with Mr. Holt all through the railway mania in opposing and projecting numerous lines of railway, in all parts of the kingdom, and afterwards sinking and laying out several collieries in Yorkshire.

In 1860 Mr. Childe joined Mr. Holt in partnership, the connection lasting until the death of the latter in 1869; since which date Mr. Childe acted as mining engineer to most of the principal proprietors in the district. Mr. Childe, in addition to being mining adviser to the North Eastern Railway Company, was continually engaged in arbitrations.

Mr. Childe was conspicuous for his unimpeachable integrity, and for exercising the full amount of his energies on whatever business he was engaged upon: his motto being "thorough." He was modest and unostentatious, shrinking from any kind of publicity, and was one of the most just men in the profession.

Mr. Childe was elected a Member of the Institution, on the 4th of December, 1883, and he died on the 30th of July, 1886, aged sixty years.

HAMILTON HENRY FULTON was a son of Mr. Hamilton Fulton, civil engineer, who, after having been engaged in some of the most important works of Mr. John Rennie, senior, and of Mr. Telford, Past-President Inst. C.E., was appointed in 1819 State Engineer to North Carolina and Georgia, U.S. Mr. H. H. Fulton was born in 1813, at Charles Street, London. He accompanied his parents to America, and was educated at the Athens University, Georgia. After the return of the family to England in 1829, he became pupil to his father, and on the death of the latter in 1834, he was at once placed upon important works by the younger John Rennie, then recently knighted. In 1839 he was engaged upon the Newcastle and Carlisle Railway, and three years later had become resident engineer for the reclamation works of the Wrigland district at the mouth of the River Nene. On the 6th of May 1845, Mr. Fulton was elected a Member of the Institution. About the year 1846 he commenced practice in the Adelphi, and soon afterwards removed to Great Queen Street, and subsequently to Great George Street, Westminster.

Among the earlier works for which Mr. Fulton was engineer from the inception of the Parliamentary plans to completion, were the West London and Crystal Palace Railway, with the branches to the London and Brighton line at Norwood and at Battersea. In the construction of this line Mr. Fulton acted in conjunction with the late Mr. G. P. Bidder, Past-President Inst. C.E. The works were heavy, and one of the tunnels passed immediately under the Crystal Palace. This undertaking, the forerunner of the present system of suburban railways south of London, now forms part of the main line of the London Brighton and South Coast Railway having its terminus at Victoria. Among other works, followed, in 1855, the extension, by the Stokes Bay Railway and Pier Company, of the London and South-Western Railway to Stokes Bay, for the purpose of improving the communication with the Isle of Wight; and the Ryde and Ventnor Railway; in 1856, an extension by the Milford Railway Company of the South Wales broad-gauge railway to Milford; in 1860, the Salisbury and Dorset Junction Railway, and from 1859 to 1863 the surveys and Parliamentary plans for the Act known as the Manchester and Milford Railway. About this time also Mr. Fulton's scheme for crossing

the Severn, and thus connecting the Great Western Railway system, at a point near the Chepstow bridge, with South Wales, became known. The main feature of this project was a bridge eclipsing in magnitude any hitherto constructed except on the suspension principle. The main span was 600 feet, and the height above high-water 95 feet. Besides this there were to have been two spans each of 265 feet; thirty spans of 150 feet, twenty-six of 120 feet, and twenty-seven of 90 feet each. Under the title of the South Wales and Great Western District Railway, the scheme was brought before Parliament in the Session of 1865, with Mr. (now Sir John) Fowler, Past-President Inst. C.E., and Mr. H. H. Fulton, as engineers. Beyond this stage the work did not proceed, but the recently completed Severn Tunnel connecting the Great Western system with South Wales, and having therefore the same object, is only a short distance below the line of Mr. Fulton's proposed bridge. About this period another proposal, made by Mr. Fulton in advance of the times, was to cross the River Mersey between Liverpool and Birkenhead by a high level railway bridge. In this case the spans were to have been 400 feet. The superstructure was to consist of lattice girders giving a clear headway of 120 feet above high water, and the distance from shore to shore, in the line of the bridge, was about three-quarters of a mile. But like the Severn, the Mersey was destined to be first crossed by a tunnel, and this work, opened during 1886, has been carried out on the same line as the bridge proposed more than twenty years ago by Mr. Fulton.

But railway engineering in this country had rapidly declined, and Mr. Fulton, born and nurtured in the strength of the early railway-times, only attained his professional maturity in their decadence. His active mind had long been intent on other branches of engineering. Sewerage and water-supply more particularly engaged his attention, and in May 1867, his well-known scheme for the future water-supply of the Metropolis was laid before the Royal Commission on water-supply. At that time two great projects for a supply by gravitation from Wales were considered. By the Northern scheme introduced by Mr. Bateman, Past-President Inst. C.E., it was proposed to impound the head waters of the Severn, including the rivers Tanat, Vyrnwy, and Banw. The Southern scheme advocated by Mr. Fulton included the head-waters and upper tributaries of the Wye. In favour of his scheme Mr. Fulton wrote, "The Wye-basin being more thinly inhabited than the other large river-basins of England and Wales, its water is at present of less utility, and its proposed abstraction will be of less inconvenience than in any other case." Mr. Fulton's

estimate of the net rainfall available for water-supply and compensation to the river was 30 inches per annum, and subsequent observations seem to justify his expectations. The total drainage-area stated to be available was divided into four districts, covering 281,761 acres, or 440 square miles; but of this it was proposed, in the first instance, to utilize only No. 1 district, having an area of 93,752 acres, or 146 square miles. Upon this smaller area, Mr. Fulton had laid out six reservoirs, having an aggregate capacity of 26,250,000,000 gallons, and yielding, on the basis of Mr. Fulton's moderate estimate of the rainfall, 130,000,000 gallons a day for London, after allowing as compensation to the rivers one-fourth of the available rainfall, a condition which, while diminishing the floods, would have more than doubled the dry-weather flow. The proposed aqueduct to London commenced in No. 1 district at the most southerly of the impounding-reservoirs in the Elan Valley. The altitude here is about 590 feet above Ordnance Datum, and the aqueduct, as then laid out, would have had a total length of about 180 miles to the service-reservoirs at Totteridge, near Barnet, at an elevation of 276 feet above Ordnance Datum, and at a distance of 8 miles from the Marble Arch. The estimate for this first section of the scheme was at that time £7,000,000. It is now eighteen years since the Royal Commission sat for the investigation of the various schemes proposed for the water-supply of the Metropolis. Liverpool has already appropriated a portion of the Northern scheme, including the upper waters of the River Vyrnwy, with its tributaries, the Cowny and Marchnant. Large areas for the supply of pure water in this country become rarer year by year; but the district selected by Mr. Fulton is little, if at all, changed, and if ever the Metropolis seeks a supply from a distant source, it is probable that part at least of Mr. Fulton's scheme will be included.

The last project of importance with which Mr. Fulton was intimately connected, was that of the Manchester Ship Canal. He conceived that a waterway to connect Manchester with the sea, to be worthy of the support of the Manchester people, must be a navigation unbroken by locks—a channel along which vessels might pass in either direction without hindrance at any time. The idea was a bold one, and although on the one hand it involved difficulties, from which the old system of inland-navigation was free, it promised on the other benefits which the locking-system could not afford. As a matter of construction, the amount of excavation was necessarily greater in Mr. Fulton's plan; but as

the water-level was lower, railways would have been passed under with more moderate alterations of their levels. At Manchester the hulls of vessels would have been much below the general surface of the ground; but in point of discharging the disadvantage of this is less than might appear at first sight. However discharged, cargo must be placed in hoists of some kind, and the extra charge upon the goods for increased height of lift would be insignificant. Mr. Fulton's scheme appears to have become publicly known in 1876, and early in 1877 it was brought under the notice of the Manchester Chamber of Commerce by Mr. George Hicks. In April 1877, the Chamber held a special meeting on the subject, and adopted a resolution to the effect *inter alia*, "that it would be of the greatest service to the interests and trade of the district to have an improved waterway." It was not, however, until 1882 that any further important step was taken. At a meeting held on the 27th June in that year, at the residence of Mr. Daniel Adamson, M. Inst. C.E., the present Chairman of the Manchester Ship-Canal Company, Mr. Fulton explained at length his scheme to more than seventy representative men, including the mayors of the various towns interested. The project included the formation of a trained channel from the deep water of the Upper Mersey Estuary, near Garston, to Runcorn, and of a tidal canal from Runcorn to Manchester. At Manchester the depth of water at low tide was to be 22 feet, which, added to 15 feet rise on ordinary spring-tides, would give 37 feet at high water. The entire length of the proposed canal would be 37 miles; its minimum width at the surface 228 feet, and at the bottom 80 feet. At Manchester, there was to be a basin 8,000 feet long and 700 feet wide, having an area of 128½ acres, and more than 3 miles of quayage. The estimated cost was £4,500,000. At this meeting a provisional committee was formed with powers to obtain a detailed survey. On the 7th of July following, Mr. Fulton and Mr. Leader Williams, M. Inst. C.E., were appointed engineers, and instructed to make a survey and to furnish a joint report. Mr. Williams, however, had already given his allegiance to the lock-system, and it is no cause for surprise that two engineers, starting upon such radically different principles, should fail to agree and find it necessary to present independent reports. This, as a matter of fact, they did; and finally, on the report of Mr. Abernethy, Past-President Inst. C.E., in favour of the lock-system, Mr. Williams's scheme was adopted on the 26th September, 1882. Thus ended Mr. Fulton's connection with another great project.

Mr. Fulton died on the 10th of August, 1886, at his residence,

Bedford House, Chiswick, in his 74th year. In this short review of his professional life, it has only been possible to refer to some of the principal works which he carried out or projected; but it is sufficiently obvious that the very foresight which placed some of his projects in advance of the times often proved of less value to him from a business point of view than to others who, at later periods, though possibly in a modified form, gave practical realization to those projects.

WILLIAM MORRIS, third son of the late John Morris, of Poplar, architect and surveyor, was born at Blackwall on the 24th May 1836, and was educated at schools in that district and in Cambridge, finally studying for three years at King's College, London. He was then articled for five years to Mr. John Seaward, M. Inst. C.E., mechanical engineer, two of which he spent in the workshops, and the remaining three years as a leading draughtsman, Mr. Seaward at that time employing no fewer than one thousand men. In 1861 Mr. Morris received an appointment under Mr. George Wilson, M. Inst. C.E., of Parliament Street, for whom he surveyed several important Welsh railways. In 1863 he was manager to Mr. Benjamin Piercy, M. Inst. C.E., who was then engaged on numerous works, both at home and abroad; amongst these may be mentioned a railway through the island of Sardinia for the Italian Government, the survey and setting-out of which were undertaken by Mr. Morris. On leaving Mr. B. Piercy, Mr. Morris entered the service of the East London Waterworks Company, under the late Mr. Greaves, M. Inst. C.E. While connected with this Company he gained considerable experience in this branch of the profession, and by his steady and continuous labour won the confidence of all with whom he came into contact.

In 1869 he was engaged by the Imperial Gas Company at Haggerston, and about this time he also received the appointment of Engineer to the Native Guano Company to test at their works at Crossness the system of sewage-utilization which they desired to recommend to the Metropolitan Board of Works.

In 1873, on behalf of Mr. W. R. Kinipple, M. Inst. C.E., he visited Newfoundland to make the preliminary surveys, and to obtain information in order to report on the proposed addition to St. John's waterworks (subsequently carried out by the firm); and in the same year he also visited Quebec for a similar purpose in connection with the proposed harbour improvements. In 1874 he joined Mr. Kinipple in partnership, and that subsisted until his death. The firm of Kinipple and Morris was engaged

upon a number of colonial undertakings, in connection with which Mr. Morris was frequently abroad; thus in 1875, and every succeeding year, with one exception, down till 1883, he visited Quebec to make surveys and superintend during progress the harbour improvements for which the firm were engineers. These improvements comprised the Louise embankment, the new wet-dock, and the new graving-dock at Point Levis. The firm acted as chief and consulting engineers to the Quebec Harbour Commissioners from the commencement of the harbour improvement works in 1877 until the year 1883, and from 1883 to 1886 as consulting engineers only. In 1874 Mr. Morris visited Victoria, British Columbia, to examine and report upon the graving-dock and other works at Esquimalt, proposed to be constructed at the joint expense of the Imperial, the Dominion, and the British Columbian Governments. Contract drawings and specifications for the works were subsequently prepared by the firm, and the works were carried on under their superintendence, and are now nearly completed. In 1877 the firm were requested to report on the site of the graving-dock at Halifax, N.S., when Mr. Morris visited that city, and obtained the necessary financial and engineering information for the scheme. In 1880 he directed the survey of a line of railway for the Government of Newfoundland, through a difficult and rugged country, from the city of St. John to Harbour Grace, a distance of about 100 miles. A considerable portion of the country traversed by the projected line had previously been unexplored. Contract-drawings and specifications for the construction of the works were subsequently prepared. In addition to these works, the firm was engaged upon many undertakings at home, amongst which may be mentioned the construction of a graving-dock at Blackwall for Messrs. R. and H. Green, the Mynydd Mawr Railway, South Wales, a sugar refinery at Silvertown for Messrs. Lyle, &c.

Mr. Morris was the patentee of several engineering inventions, the last of which came prominently before the public two years ago, in connection with the River Thames communication. He was elected an Associate of the Institution on the 7th of May, 1872, and became a Member on the 15th of January, 1878. He was a man of remarkable energy, a good mathematician, and was ever ready to help those who asked his advice either professionally or privately. His keen intellect was incessantly on the alert, even indeed during the last days of the long illness which terminated fatally on the 22nd of September 1886, when in his fiftieth year.

PARKE NEVILLE was born in Dublin, in the year 1812, and was the eldest surviving son of the late Mr. Arthur Neville, who was surveyor to the Corporation of Dublin, and Engineer and Designer of the Grand Canal, Dublin, one of the most celebrated works of its day. Mr. Neville's ancestors for three generations before him were all connected with the engineering and surveying profession in Ireland. In early life Mr. Neville was an articled pupil of the late Mr. Charles Vignoles, Past-President Inst. C.E., and whilst with him, and afterwards, was engaged on many important railway works in Ireland, amongst which were the Dublin and Kingstown, the Great Southern and Western, and the Midland Great Western Railways, and for a short time he was engaged on works in England. After leaving Mr. Vignoles, he served a pupilage with the late Mr. William Farrell, then Architect to the Ecclesiastical Commissioners for Ireland. Whilst in private practice, Mr. Neville made good use of his tutelage under two men, then so eminent in their professions, and thereafter combined the professions of engineer and architect, and as such carried out many public works in connection with the building of prisons, asylums, and churches, and was also engineer and architect to some of the first families in Ireland.

In April 1851, he competed successfully for the office of City Engineer to the Corporation of Dublin, and with an energy characteristic of him, immediately set about many alterations and improvements which were sadly needed. When he entered office he found the streets in a deplorable and neglected condition, many of them being practically impassable for vehicular traffic; he recommended the paving of all the principal streets with square-sett paving, and re-forming outlying macadamized streets, and bringing them up to a proper cross section. So early as the year 1853, he prepared a plan for the main drainage of the city, with all the necessary intercepting sewers, and proposed that all the sewage on the north side of the city should be discharged at the east wall near Clontarf Island, and that of the south side near Ringsend. Up to this time all the sewers in Dublin had been built with perpendicular side-walls, sometimes arched over, but in many instances covered with flags; all had flat bottoms, sometimes paved with common boulder-stone, but more frequently the bottom consisted merely of the gravel or clay stratum on which the sewer was built. Year by year, according as the funds of the Corporation permitted, he re-built and re-modelled the sewers on the most improved principle, and finally, under loan from Government

in the year 1880, practically completed the sewerage of the city, leaving nothing to be desired but the carrying out of the great aim and ambition of the latter years of his life, the main drainage of the city. For this he, in conjunction with Sir Joseph Bazelgette, Past-President Inst. C.E., prepared, in the years 1869, 1870, elaborate plans, and an Act of Parliament was obtained in the year 1871. The design was to construct a high- and low-level system of sewers, north and south of the River Liffey, very much on the lines proposed by Mr. Neville in 1853. These sewers were to communicate with a large pumping-station which was proposed to be built at Annesley Bridge, from which all the sewage was to flow by gravitation to the great waste of sand at Dollymount, known as the North Bull, where outfall tanks were to be built, so as to regulate the discharge of the sewage according to the state of the tide. The scheme was designed to provide for the discharge of the sewage, not alone of the city of Dublin, but also of the Pembroke, Rathmines, Kilmainham and Clontarf townships. Tenders were obtained for these works, the lowest being £775,000; but the Corporation, on further deliberation, did not consider they were justified in spending such a large sum of money and increasing the already heavy taxation. Accordingly assistance was sought from the Government, which not being granted the Act was allowed to lapse. But the Royal Commission which sat in Dublin in 1879, of which Sir Robert Rawlinson, C.B., M. Inst. C.E., was chairman, recommended the carrying out of the system of main drainage for the city and townships on the plan proposed by Mr. Neville.

Mr. Neville's most successful work was the Dublin Corporation Waterworks, carried out in conjunction with the late Sir John Gray. The Bill for this undertaking met with the most determined opposition. Pamphlet after pamphlet was written to prove that the Vartry could not yield the supply of water required, that the system proposed was extravagant, and the cost exorbitant, &c. He had the satisfaction of living down all these objections, and seeing the works carried to their present state of perfection. Previous to the construction of the Vartry Works, Dublin was supplied with water from the two canals which surround the city, the Grand Canal on one side augmented by water taken from the River Dodder, and the Royal Canal on the other. Many parts of the city were situated at levels equal to or higher than that of the canals, so much so that no pipes were laid in them, and for the rest the supply was intermittent. The Vartry Works now supply, with a constant service, not only the city of Dublin, but also the Bray,

Killiney and Ballybrack, Dalkey, Kingstown, Blackrock, Pembroke, Kilmainham, Drumcondra, Glasnevin and Clonliffe, and Clontarf townships, as also districts which are not included in any township, and which embrace Dundrum, Rathfarnham, Roebuck, Terenure, &c., the entire covering an area of about 12 miles long by 5 miles wide at its broadest point. The Vartry rises in the Sugar Loaf Mountain, County Wicklow, and has a drainage area of 14,080 acres for the purposes of the impounding reservoir, which has a capacity of 2,400 millon gallons, the top water being 692·45 above Ordnance Datum. The water flows from this reservoir into a system of eleven filter-beds, after which it passes into two pure-water tanks; thence it is conducted by a 48-inch pipe into a tunnel 2½ miles long, from which it flows over a measuring-weir into a circular basin, and thence by a 33-inch main, with relieving-tanks, to the distributing-reservoirs at Stillorgan. A third reservoir has lately been added, thereby increasing the storage at the distributing end, so as to provide for probable emergencies in cases of accident to the main pipe-line. From this point the water is conveyed to the city by a double line of 27-inch mains. These works were completed at a cost of £650,000. All Mr. Neville's energies were exerted to insure success, and the contract-drawings of many of the most important and intricate portions were made by Mr. Neville himself, such was his anxiety for their perfection. The revenue for contract-water in the city has risen from about £1,600, which was the total in 1861, to £27,135 in 1885. Year by year the revenue from this source has steadily increased, as also from the townships and extra municipal districts, so that the Corporation in 1885 were enabled to reduce the taxation for water from 1*s*. 3*d*. in the £ to 1*s*. 0½*d*. Of this enterprise Mr. Neville contributed a description to the Institution in 1874.[1]

Mr. Neville also designed and built an efficient little waterworks at the fifth lock of the Grand Canal, for the supply of the breweries and distilleries of Dublin, in order to give them the same quantity of water (but at a higher level) which they were using before the introduction of the Vartry. He also designed and carried out a fine cattle market, the divisions of which are all of iron, capable of accommodating five thousand head of cattle, and thirteen thousand eight hundred and fifty sheep, and occupying an area of 10 acres. The sheep-pens are concreted, and the cattle-pens, roads, and alleys, are paved with square sett paving grouted with tar. The entire cost of these works has been £36,000. The market

[1] Minutes of Proceedings Inst. C.E., vol. xxviii. p. 1.

communicates by a sub-way under the adjoining road, with an abattoir, also designed by Mr. Neville, the cost of which has been £15,000. It stands on a plot of ground, containing 9½ acres. Within the last few years, Mr. Neville carried out large paving works in the city on the most improved system, the work having been done under a loan of £100,000 from Government, and at the time of his death, he was engaged in similar paving work under a second loan of £100,000.

Amongst many other street improvements, Mr. Neville had the satisfaction before he died, of opening up and building a new street at a cost of £70,000, connecting Dame Street with Christ Church Place, having an easy gradient of 1 in 43 as against an old tortuous route through Cork Hill, which in places was as steep as 1 in 12. The making of this street was in abeyance for over forty years, until at length, by dint of continually bringing it before the public, the matter was finally carried.

Mr. Neville was elected a Member of the Institution on the 5th of December, 1865. He was also a Past-President of the Institution of Civil Engineers in Ireland, a Vice-President of the Institute of Architects, and was likewise a member of many Literary and Scientific Societies in Dublin. He was a man of sterling character, upright and straight forward in his dealings with his fellow-men, and most conscientious in the performance of his public duties, which were discharged by him with unswerving fidelity. He was slow in forming an opinion; but when once formed he maintained it with energy and determination.

During his holidays in the autumn of 1886, Mr. Neville visited several towns in England for the purpose of examining and inquiring into the systems of public baths and wash-houses, so as to utilize the information thus gained for Dublin. He also attended the Meetings of the British Association, and returned to Dublin early in October, with the evident traces of illness in his face. He died at his residence in Pembroke Road, Dublin, on the 30th of October, 1886, after being absent from his official duties for only two days.

JOHN SCOTT RUSSELL, F.R.S., died at Ventnor on the 8th of June, 1882, after a long illness. He was born in the year 1808, and was thus the contemporary of Robert Stephenson, of the younger Brunel, of John Penn, and of most of the great engineers who have made this century illustrious.

He was the only son of the Rev. David Russell, a Scotch

minister, by his first marriage. His birth-place was Parkhead, near Glasgow, and he was destined by his father for the church, and was educated accordingly. Early in life, however, he showed a great leaning towards science and practical mechanics, and eventually obtained permission to abandon the clerical education, and fit himself to become an engineer. He does not appear to have ever served a regular apprenticeship. His first knowledge of practical work and of the use of tools was gained in the village blacksmith's shop adjoining his father's house, where he worked with all the greater assiduity, because his studies were at first discouraged in every way possible. His scientific education was excellent, and as complete as could be obtained at that day. It was indeed in the extent of his theoretical knowledge that John Scott Russell was most distinguished amongst the engineers of his day. He studied at the Universities of St. Andrews, Edinburgh and Glasgow, and graduated at the latter place at the early age of sixteen. He completed his knowledge of practical handicraft by working during his vacations and leisure hours at the factories of various mechanics and millwrights.

His career was remarkable and varied. He was by turns, schoolmaster, University professor, experimentalist, ship- and engine-builder, secretary of a scientific society and of the Great Exhibition of 1851, and finally consulting-engineer and author. He commenced supporting himself when he was eighteen years of age; but he does not appear to have at that period found an opening in the engineering profession, for, with one of his friends, he settled down in Edinburgh, and founded a preparatory school for the University, called the South Academy, which exists to this day. It was no doubt due to his early training in the art of instruction that he acquired that force and clearness of expression, which was one of his leading characteristics, and which never deserted him even when expounding the most difficult subjects. While conducting the South Academy he was encouraged by the example of his old professor of geometry from St. Andrews, to commence science classes at Leith, and at Edinburgh University. Here he rapidly acquired great reputation as a lecturer and teacher. His original method of treating difficult questions, and the simplicity and clearness of his exposition produced a deep effect on the students of the University, and it is stated of him, so great was his popularity, that when he commenced his second course of lectures, the class-rooms of his former master and actual rival, the St. Andrews professor, were rapidly emptied. He continued this work of private tuition at Edinburgh for about six years, but at

the same time he did not neglect the engineering profession, for during this period he was engaged in a series of experiments on steam-engines and boilers, and invented the system of staying the inner and outer shells of the flat surfaces of boilers which has since become universal.

In 1832 an event occurred which was the means of bringing young Scott Russell into general notice. Sir John Leslie, the well-known Professor of Natural Philosophy at Edinburgh University, died; and, pending the election of a new professor, Scott Russell, though at the time only twenty-four years of age, was chosen to fill the vacancy *ad interim*. In this capacity he delivered a course of lectures on Natural Science to the students of the University. Many of his friends urged him to offer himself as a candidate for the permanent professorship. Understanding, however, that Brewster, for whom he had the greatest admiration, stood a good chance of being elected, he declined to put himself in competition, and he persevered in this refusal even after it became known that Forbes was to be a candidate. Mr. Forbes was ultimately elected, and shortly afterwards Scott Russell's connection with University life in Edinburgh seems to have terminated.

He thenceforward devoted himself to the practice of the engineering profession, and to experimental research on a large scale. The year after he left Edinburgh University he appears to have been consulted by the directors of a Scotch Canal Company as to the practicability of introducing steam-propulsion on canals. It was this incident which caused him for the first time to devote his attention to the great subject of the resistance which water opposes to the propulsion of floating bodies, with which his name came to be afterwards identified. In reply to the inquiry of the canal-directors, he stated, that neither he nor anybody else could give an opinion of any value on the subject; but, that he was prepared to investigate the subject experimentally, provided they would authorize him to do so, and would place a portion of the canal at his disposal for the purpose. This proposal was agreed to, and led to the undertaking of the series of experiments on the nature of waves, and on the resistance of water to the motion of floating bodies, which ultimately paved the way to the introduction of the modern system of naval architecture. This was in the year 1833, and he must have worked hard at his experiments, for in the following year he read his first Paper before the British Association, in which he deals with the resistance of fluids to the motion of floating bodies. This was followed up by another Paper in the year 1835 on the laws of motion of floating bodies; but

owing to the publication, at that period, of short and imperfect abstracts, only slight reference to these Papers appears in the Annual Reports. It is, however, easy to infer from the abstracts, that he had already made his first great discovery in wave-motion, that of the existence of travelling as distinguished from oscillating waves; for in the 1835 Paper he mentions that the motion of a floating body is much facilitated when its velocity is so great that it can travel on the summit of the wave which it has generated. These remarks evidently refer to the propulsion of canal-boats, and the discovery of the travelling wave, or the wave of translation as he afterwards termed it, led to his introducing the system of express canal-boats, in which the boats were dragged by galloping horses on the summit of the waves which their motion generated in the canal, and at speeds corresponding to the natural velocities of such waves for the particular depth of water found in the canal.

The next year, at the Bristol meeting of the Association, Mr. Scott Russell and Sir John Robinson, Secretary to the Royal Society of Edinburgh, were appointed as a committee to investigate the whole subject of waves. The following year, 1837, they presented their preliminary report, which was written by Mr. Scott Russell, and which is an excellent example of his clear reasoning-powers and literary ability. The report, which is very lengthy, contains the records of a series of observations on the ordinary waves of the sea, tidal-waves, and on the effect of river-estuaries in modifying the tidal-wave, waves generated in canals and other confined channels, together with the conclusions drawn from the observations. In this report, Mr. Scott Russell describes in detail the wave of translation which he states that he discovered in 1834. At the same meeting of the Association he read three Papers of practical interest showing the applications of some of his discoveries. One was entitled, "On the Mechanism of Waves in Relation to the Improvement of Steam-Navigation," the second was "On Improvements in Tidal Rivers," and the third "On the Construction of Sea-Walls and Embankments." In the first of these Papers he dealt with the impediments to steam-navigation, due to the limited depth of most rivers and canals, and also announced, it is believed for the first time, his wave-line system of shaping the hulls of vessels for the purpose of diminishing the wave-making resistance. Owing to the unfortunate practice of the Association already referred to, of only publishing abstracts of their Papers, the announcement of this important discovery was condensed into a single sentence of under three lines of letter-press. In the same

year, however, he read, before the Royal Society of Edinburgh, a Paper "On the Laws by which water opposes Resistance to the Motion of Floating Bodies," for which he was presented with the gold medal of the Society, and was also elected a member of its council; he had at this time already been for some years a Fellow. The final report on waves was presented at the York meeting of the Association held in 1844. It is an exhaustive and closely-reasoned Paper of over eighty pages of letter-press copiously illustrated.

Before noticing the practical improvements which Mr. Scott Russell introduced into the structure and forms of ships, it should be mentioned that he presented to the British Association in the year 1842, a report on the forms of ships which contained the record of the almost incredible number of twenty thousand observations, the result of careful experiments on the resistance experienced by models of ships of more than a hundred different forms and sizes, and extending from small vessels of 30 inches long to vessels of 25 feet, 60 feet, and 200 feet long, and above 1,000 tons burden. The Reports of the Association for the years 1843 and 1845, contain short abstracts of this Paper, which was never published *in extenso* on account of the expense that would have been involved. It is, however, a matter for everlasting regret that the original report has been lost, though the numerous plates which illustrated it still survive, together with tables of some of the results attained, and are now in the care of the Institution of Naval Architects. In one of the short published abstracts of the report, in commenting upon previous experiments in the same direction made by others, Mr. Scott Russell objects to them, on the ground (amongst others) that at the time they were carried out, "it had not been established by what law the results of experiments on one scale of magnitude are to be transferred to a different scale, either greater or less." From this it may be inferred that in his own experiments he was in the habit of using a law by which he applied the results of model experiments to actual ships. In the absence of the report itself it is impossible to decide. It is at any rate certain that in his own practice as a shipbuilder he was invariably guided by the results of experiments made on models. It must be acknowledged, that the great merit of having discovered and published the law in question belongs to the late Mr. W. Froude, M. Inst. C.E., who described it to the Institution of Naval Architects in the year 1874, thirty-two years after the date of Mr. Scott Russell's report. The experiments, to the interpretation of which Mr. Froude applied his law, were the first systematically carried out since the publication

of the abstract of Mr. Scott Russell's report; and it is worthy of remark that all that is known of his methods of experimenting, in the absence of the original of the report, is obtained from his own remarks which followed the discussion of Mr. Froude's Paper.

As may readily be supposed, Mr. Scott Russell was not long in applying the knowledge gained by his experiments to the practical business of naval architecture. His improvements in ship-design may be classified under two headings. First, those relating to the forms of ships, which were the direct result of his experiments on waves, and which took the direction of giving to the lines of the ship the forms that he found reduced the wave-making resistance to a minimum; and second, improvements in the structural design, and distribution of the material in the hulls of iron ships.

The first vessels on the wave-line system were built in 1835, and were called the "Skiff," the "Wave," and the "Storm," and were followed in the next year by the "Scott Russell," the "Flambeau" and the "Fire King." Mr. Scott Russell was, at this time, practically engaged in shipbuilding as manager to the yard which is now owned by Messrs. Caird & Co., of Greenock. When the Royal Mail company were about to build a new fleet, he succeeded in inducing the directors to introduce his system into the construction of their vessels, four of the largest of which, viz., the "Teviot," the "Tay," the "Clyde," and the "Tweed," were designed and built by him.

The structural improvements which he introduced into the design of iron ships were numerous. The present system of plating the hull with alternate in-and-out strakes was first devised by him. Before he introduced this improvement iron ships were invariably either clinker- or flush-built. He also invented the longitudinal system of building, and was the first to introduce cellular double bottoms; and in conjunction with the late Mr. I. K. Brunel, V.P. Inst. C.E., he borrowed from bridge-builders the idea of making a ship into a huge box girder by the use of a continuous iron deck. The longitudinal system was made use of in the construction of the "Storm," mentioned above, which was the second iron vessel built by Mr. Scott Russell. This vessel was constructed without a single frame, the transverse strength being provided for by complete watertight bulkheads, spaced apart by about the beam of the ship; while bars of T iron were riveted to the longitudinal joints of the skin plating, thus forming continuous longitudinal stringers. This system of longitudinal girders, combined with numerous complete and partial bulkheads, and the subsequent addition of

a continuous iron deck—and, whenever desirable, a complete or a partial double bottom—was afterwards developed into a very perfect method of construction, and was adopted by Mr. Scott Russell whenever owners gave him permission to follow his own bent. Amongst the best known vessels built on this system were the "Baron Osy" and "El Rey Jaime I." in 1855, "El Rey Jaime II." in 1858, and subsequently the "Annette" and the crowning development the "Great Eastern." The system was fully described in a Paper read by Mr. Scott Russell before the Institution of Naval Architects in 1862. It may here be noticed that it was not generally adopted, even in a modified form, by mercantile shipbuilders till about the year 1879, when, in consequence of the general introduction of water ballast, numbers of steamers were built with their bottoms constructed on the longitudinal or cellular system. Even then, it must be remarked, that it was the requirements of the water ballast and not the desire to obtain increased longitudinal strength which led to the partial adoption of a longitudinal system of construction. On the other hand, Mr. Scott Russell's ideas were at an early period taken up by the Admiralty, and subsequently developed in accordance with the special requirements of war ships. To ironclad war ships the system seemed peculiarly adapted, not only because of the great longitudinal strength secured, and which in such ships is often imperatively required by the presence of heavy end weights, but also because the safety of war ships, if penetrated at or below the water-line, requires a minute subdivision of the hull, which can only be obtained by the numerous bulkheads, partial and complete, which form an essential feature of the system. The longitudinal system of framing is also peculiarly adapted to the construction of the bows of ships intended to be used as rams.

The two first armoured iron ships of the navy, viz., the "Warrior" and the "Black Prince" were in all their essential features built in agreement with the views of Mr. Scott Russell, whose large experience as an iron shipbuilder and scientific naval architect was freely placed at the disposal of the Admiralty. The framing of each of these ships was a combination of the longitudinal and transverse systems. There were six longitudinal frames on each side of the keel, the uppermost one forming the armour shelf. Between these, transverse frame plates were fitted, and inside of the latter were the transverse frames, which provided for the athwartship connection, and which extended up behind the skin plating and the armour and backing. These ships were also provided with two iron decks, but had only very partial inner bottoms.

A peculiar feature of the construction was a longitudinal vertical bulkhead, placed about 3 feet from the inside of the frames on each side of the ship, and extending from the main deck down to the bottom framing. These longitudinal vertical bulkheads played, to a certain extent, the part of webs to an ordinary girder, and conferred great additional strength on the entire structure; they also give great facilities for increasing the watertight subdivision of the hull. The system of framing above referred to was afterwards modified by Mr. (now Sir Edward) Reed, M.P., in the construction of the "Bellerophon." The heavy transverse frame plates were done away with, and comparatively light bracket plates substituted for them. The longitudinals were greatly deepened, and a continuous double bottom over the greater portion of the ship was provided. This bracket plate system of framing combined with longitudinal stringers is in all its main features the standard system of construction of the bottoms of war ships at the present day.

The greatest shipbuilding exploit which Mr. Scott Russell achieved was, without doubt, the construction of the "Great Eastern." The original conception of this great triumph of engineering lay with Mr. I. K. Brunel, whose idea was to construct a vessel large enough to be able to carry coals sufficient for full steaming on the longest voyages. Mr. Brunel at the outset, and long before his views had attained a mercantile form, communicated them to Mr. Scott Russell, who shared with him in the contrivance of the best means of carrying them into practical effect. The idea of propelling the vessel by means of both paddles and screw was Brunel's, as was also the application of the cellular construction of the top and bottom of the ship, which was adapted from the Britannia Bridge. In other respects the ship embodies the wave-line form, the longitudinal system of construction, the complete and partial bulkheads, and other details of construction which were peculiarly Scott Russell's, and which he had systematically carried out in his own practice for the twenty years preceding the building of the great ship. He was also, of course, as naval architect, solely responsible for the design of the ship, as far as regarded all questions connected with displacement, stability, scantlings, and the amount of horse-power required to attain the proposed speed. He further had the sole merit of the design and construction of the magnificent paddle engines, which are even yet the largest that have ever been constructed. As practical shipbuilder, he devised the means of carrying out the design of this huge vessel, which was at the time, and remains to this day,

the largest iron structure that has ever been put together. If there be borne in mind the difficulty, in the actual state of engineering knowledge at that time, of calculating the strength, and consequently of designing this vast vessel, which had to undergo not merely the statical strains usual in land structures, but also the dynamical strains due to rolling and pitching and to the impact of heavy seas; and if there be remembered, further, that the "Great Eastern" has never shown the slightest signs of structural weakness, though frequently put to uses for which she was never intended, it must be acknowledged that she is a monument to the genius of the two great men who shared the merit of her conception and design.

In summing up Mr. Scott Russell's connection with the profession of naval architecture, it may be said that on commencing his career he found it the most empirical of arts, and he left it one of the most exact of engineering sciences. To this great result many others contributed largely besides himself; but his personal investigations, and the theories which he deduced from them, gave the first impetus to scientific naval architecture; his practice for a long time led the way, and his action in organizing the profession for scientific purposes, by founding the Institution of Naval Architects, entitles him to a preponderating share in the merit of that which has been accomplished in the last half century.

In endeavouring to describe the improvements in the design of ships due to Mr. Scott Russell, the chronological account of his professional life has been necessarily interrupted. He remained in Scotland till the year 1844, and during the twelve years which he spent in his native country, after severing his connection with Edinburgh University, he distinguished himself in engineering pursuits as well as in shipbuilding. Some of his earliest experiments while still at Edinburgh were on engines and boilers. When at Greenock, he built a steam-carriage for common roads, which ran regularly for hire between that town and Paisley. It was remarkable chiefly for the ingenuity of its springs and the connections of the moving parts of the engine, which rendered the latter completely independent of the inequalities of the roadway. The late Mr. John Head, M. Inst. C.E., has described these steam-carriages, in a Paper[1] which he read before this Institution in the year 1873, as having been amongst the most successful ever constructed. In the year 1834 there were six of them running regularly between Greenock and Paisley. Their use was abandoned

[1] Minutes of Proceedings Inst. C.E. vol. xxxvi. p. 36.

chiefly in consequence of the opposition of the road-trustees, who placed every conceivable impediment in their way, at last causing a serious accident, which resulted in the death of several persons.

About this time also he wrote his earliest important treatises on "The Steam-Engine' and on "Steam-Navigation," which first appeared in the seventh edition of the "Encyclopædia Britannica," and which were afterwards published as separate books. He also, during his stay in Scotland, contributed a very brilliant series of articles to the *Athenæum*, and numerous Papers to the Royal Society of Edinburgh, the British Association, and other scientific bodies.

In the year 1844 Mr. Scott Russell removed to London, and shortly afterwards he commenced business, in partnership with Mr. Robinson, as ship- and engine-builders at Millwall. He appears, however, to have found time to interest himself in other occupations, for he took an active share in the management of the Society of Arts which was not then in a very flourishing condition. He was appointed joint Secretary to the Society in 1845, and afterwards became sole Secretary. During the period he remained in office the Society obtained a Royal Charter of Incorporation, and was fortunate enough to receive the sympathy and active support of the late Prince Consort. About this time also a project was developed by Mr. Scott Russell, the late Sir Henry Cole and a few other gentlemen, under the patronage of the Prince Consort, which was destined to be followed by important results. This was no less than the holding of a series of national exhibitions, which were the forerunners of, and actually prepared the way for the holding of the first great International Exhibition in 1851. The difficulty of organizing the first of these exhibitions appears almost incredible in face of the eagerness with which they are now taken up by manufacturers. A few days before the date appointed for the opening there were neither exhibitors nor exhibits, and Mr. Scott Russell, accompanied by Mr. Cole and another friend, spent three whole days travelling about London in four-wheeled cabs calling on manufacturers and shopkeepers, and succeeded at last, by "personal entreaty"—as they afterwards expressed it—in inducing many of them to send sufficient goods to fill the Exhibition galleries. This was the origin of Mr. Scott Russell's connection with the Great Exhibition movement, and when the Royal Commission of the 1851 Exhibition was nominated he was appointed joint-Secretary with Mr. Stafford Northcote (the late Earl of Iddesleigh), and in this capacity he played a leading part in the organization and management of that great undertaking. In one

of the published letters of the late Prince Consort his Royal Highness bore emphatic testimony to the value of Mr. Scott Russell's services. After describing the difficulties that had been encountered, it was stated "by dint of Mr. Scott Russell's tact, judgment, penetration, resource and courage, that obstacles vanished and intrigues were unmasked."

The financial troubles connected with the building of the Great Eastern caused the suspension of the firm of J. Scott Russell and Co., and after that event took place Mr. Scott Russell practised for several years in London as a Consulting Engineer. In this capacity he designed some important works; one of these was the steam railway-ferry, together with its approaches on Lake Constance, by means of which communication is maintained between the German and Swiss systems of railways which terminate on the opposite shores of the lake. The ferry-boat, which is a paddle-wheel vessel of about 1,600 tons displacement, is contrived to carry fourteen to sixteen carriages on two parallel lines. The natural difficulties in the way of carrying out this undertaking were considerable, as the harbours on both sides are exceedingly narrow, and so shallow that 6 feet was the maximum draught of water obtainable. The difficulties of manœuvring were got over by making the boat of the same shape at each end so that she could progress equally well in either direction; a rudder was also provided at each end and each of the paddles was driven by an independent pair of engines. The necessary strength on the very limited draught was obtained by making the central portion of the boat into a box girder, a central iron deck, connected to the hull by two vertical side walls, having been for this purpose erected over the deck on which stands the train. This ferry-boat, which was the last work of naval architecture carried out by Mr. Scott Russell, proved perfectly successful, and has been employed ever since 1868 in the service between Romanshorn and Friedrichshafen. It is described in a Paper published in Vol. X. of the Transactions of the Institution of Naval Architects.

Another important work designed by Mr. Scott Russell was the great Rotunda of the Vienna Exhibition of 1873. Considered as a dome this work is the Great Eastern of land structures, being the roof of largest clear span in the world. So early as the year 1850 he had contrived a similar building for the first great International Exhibition, but, like everybody else, he was so fascinated by Paxton's design for a glass and iron palace, that he never brought forward his own ideas. The dome of the Vienna Exhibition is a cone of sheet iron, 353·7 feet in diameter, standing

on wrought-iron rectangular pillars 80 feet high by 4 feet wide and 10 feet deep. The severe outline of the cone is broken by two lanterns, the lower one of which is 106·25 feet in diameter by 33 feet high, surmounted by a second conical roof on which stands the upper lantern forming the apex of the building. There is not a single tie-rod in the construction. The lower ring on which the cone rests, and which is part of its structure, is put in a state of tension by the tendency of the cone to spread outwards. Similarly the upper ring at the base of the first lantern is put in a state of compression, and throughout the whole of the structure the successive rings of which it may be conceived to be built up, commencing from the base, are in a state of tension, the intensity of which gradually diminishes upwards, till a neutral ring is reached (corresponding to the neutral axis of a girder), beyond which again the rings are in a state of gradually increasing compression. Provided the section of the metal is everywhere sufficient to resist the strain, it is obvious that internal or radial ties are superfluous, and all that is necessary is so to stiffen the surface of the cone that it cannot sag.

This was the last great work of Mr. Scott Russell's lifetime, and with its completion his career as an active engineer may be said to have terminated. As will be seen from the foregoing, though best known as a shipbuilder he by no means confined his attention to naval architecture and marine engineering. He took a deep interest in many branches of civil engineering, including even railway matters, and at one time he carried out an important series of experiments on the resistance of railway trains, the results of which he communicated to the British Association in a Paper which was published in the year 1846.

In addition to the numerous Papers which he contributed to various scientific bodies, Mr. Scott Russell was the author of some important professional treatises. The earliest of these, his works on the steam-engine, and on steam-navigation, published in the "Encyclopædia Britannica," have been already mentioned. His greatest work was his treatise on the "Modern System of Naval Architecture." He also wrote a book called "A System of Technical Education for the English People." The subject of technical education always interested him greatly; and when he was engaged in superintending the construction of the steam ferry-boat on Lake Constance, he was deeply impressed by the advantages which continental engineers and workmen derived from the excellent technical schools which were in existence all over Central Europe. He took the opportunity of studying deeply

the systems of education as adopted in Germany and in Switzerland, and shortly after his return to this country he wrote the above-mentioned book, in the hope of directing public opinion to the subject.

The most important service which Mr. Scott Russell rendered to his own profession was perhaps the part which he took in founding the Institution of Naval Architects. The original meetings of the first promoters of that Society took place at his office in Great George Street, and at his house at Sydenham, and amongst those who attended, besides himself, were Dr. Woolley, Mr. (now Sir Edward) Reed, Mr. (now Sir Nathaniel) Barnaby, Mr. F. K. Barnes, and Mr. Crosland. At one of these meetings Mr. Reed undertook the Secretarial duties and the organization of the Institution, and Mr. Scott Russell guaranteed all the expenses. At the first meeting of the Institution he was elected one of its Vice-Presidents, which office he retained till his death.

Mr. Scott Russell first became connected with the Institution of Civil Engineers on the 29th of June, 1847. He was elected a Member of Council in 1857, and was a Vice-President from 1862 to 1867. He was also a Fellow of the Royal Society, and a corresponding member of many foreign scientific bodies. He was the Author of two Papers read before the Institution: namely, "On the practical Forms of Breakwaters, Sea-walls, and other Engineering works Exposed to the Action of Waves;[1] and, "On certain Points in the Construction of Marine Boilers."[2] For many years he was one of the most constant attendants at the Tuesday-evening meetings, and a frequent contributor to the discussions, no less than five columns of entries standing under his name in the General Index to the first twenty volumes of "Minutes." In the year 1880 he was much interested in the question of the Tower bridge, and had prepared plans for the construction of a bridge of 1,000 feet span, and of a clear opening of 100 feet above Trinity high-water mark. In furtherance of this idea, he paid several visits in the following year to numerous ironmasters in the North of England and Scotland, and while going over some ironworks he caught a severe chill, which brought on an illness from which he never fully recovered. For a few months he regained strength, but experienced a relapse in the spring of 1882 which terminated in his death on the 8th of June of that year.

Mr. Scott Russell married in 1839 Harriett, daughter of Sir

[1] Minutes of Proceedings Inst. C.E. vol. vi. p. 135.
[2] *Ibid.*, vol. xi. p. 390.

Toler Osborne, Bart., of the County Tipperary, and had a family of two sons and three daughters, of whom a son and two daughters survived.

The foregoing sketch will give an idea of his professional work and public life. He was distinguished among his contemporaries for his great scientific knowledge, acquired at a period when technical education for engineers did not exist in this country. It is not often that the love of science and the inventive genius are wedded to strong business instincts and habits, and Mr. Scott Russell's case was no exception to the general rule. Had it been otherwise, he would not improbably have occupied a position higher than any he attained to. In private life he was the most agreeable and hospitable of friends. His great originality of mind lent a peculiar charm to his conversation. As a speaker, and particularly as an after-dinner speaker, he had few equals. His education was by no means bounded by the pursuits of science. He had considerable knowledge of the classics, and of general literature, and some of his earlier reports to the British Association were ornamented with long Greek quotations. He had travelled much in nearly every country of Europe, including Russia and Turkey. By his death the Institution lost one of the few great engineers of the earlier generation who survived into the last quarter of the century.

DAVID STEVENSON, the third son of the late Mr. Robert Stevenson, M. Inst. C.E., the well-known lighthouse engineer, was born at Edinburgh on the 11th of January, 1815. Educated at the High School and University of Edinburgh, he elected from the first to follow his father's profession. Before entering on his apprenticeship he was for some time in the workshops of one of the best practical millwrights of the day, where he acquired manipulative skill, and the proper methods of working in different materials, a course he always advocated for those who intended to follow civil engineering. In his Presidential Address of 1869 to the Royal Scottish Society of Arts, on "Altered Relations of British and Foreign Industries and Manufactures," he fully stated his views, urging the propriety of artisans improving their manipulative skill, and their knowledge and management of the materials with which they had to deal. After serving a regular pupilage as a civil engineer, he was for some time engaged with Mr. Mackenzie, contractor on the Liverpool and Manchester Railway, and he gave

a description of this important railway to the Royal Scottish Society of Arts in 1835, and was awarded their Medal for his exposition. He then returned to Edinburgh, and, in conjunction with his father and his brother Alan, began practice as an engineer. During the year 1837 he made a tour in Canada and the United States, the result of the inspection of the engineering works of these countries being published in a volume under the title of "Sketch of the Civil Engineering of North America," which was subsequently republished as one of Weale's Series of Engineering Works, as peculiarly applicable to newly-developed countries, where engineering works in which timber forms a chief element would yet be in full operation. The views expressed, and the drawings given in this book, with reference to the fine lines and speed attained by American river-steamers were received in this country by shipbuilders with distrust; but the bluff bows of British sea-going steamers soon gave way to finer lines, shipowners finding that great speed could only be attained by following the example of the American shipbuilders.

Mr. Stevenson's firm hold the post of Engineers to the Fishery Board of Scotland for Harbours; and his advice was much sought in regard to the improvement of rivers and harbour- and dock-works. There are indeed, very few rivers or harbours in Scotland with which he was not in some way professionally connected. He was called on to report and execute works for the improvement of the rivers Dee, Lune, Ribble, and Wear in England, the Erne and Foyle in Ireland, and the Forth, Tay, and Nith in Scotland; and extensive works are now in progress on the lower estuary of the Clyde from the designs of his firm. He was the first to enunciate the true theory of the origin of bars at the mouths of rivers, and also to define the different compartments of rivers and estuaries, and the proper treatment which each should receive for their improvement. His book on "Canal and River Engineering," giving the results of his experience in the treatment of rivers, will long remain the standard work on the difficult subject of which it treats. Originally written about thirty years ago at the request of his old friend, Mr. Adam Black, for the "Encyclopædia Britannica," it was shortly afterwards published as a separate treatise, and it is now in its third edition. In 1877 at the request of the authorities of the School of Military Engineering, Chatham, he delivered a course of lectures on Canal and River Engineering to their students. In 1853, Mr. Stevenson succeeded his brother Alan as engineer to the Northern Lighthouse Board, and, along with his brother Thomas, who was at a subsequent date conjoined with him, he designed and

executed no fewer than thirty lighthouses, two of which—on Dhuheartach and the Chicken Rocks—are triumphs of engineering skill. In addition to the Scottish lighthouses, the advice of his firm was taken by the Governments of India, New Zealand, Japan, and Newfoundland on lighthouse-matters, and under their direction schemes for the lighting of the whole coasts of Japan and of New Zealand were matured, and are now being carried out. In connection with the lighting of the coasts of Japan, where earthquakes are frequent, Mr. Stevenson devised the aseismatic arrangement to mitigate the effects of earthquake shocks on the somewhat delicate optical apparatus used in lighthouses, and received the Macdougall Brisbane medal from the Royal Scottish Society of Arts for his invention.

Mr. Stevenson frequently appeared before Parliamentary Committees, and also gave evidence before several Special Committees and Royal Commissions on Harbours of Refuge, River Improvements, and Lighthouses. He was a most conscientious witness, never entering the box without being thoroughly satisfied as to the soundness of the cause he was supporting. In Edinburgh Mr. Stevenson was greatly respected, and his advice on many important matters connected with the city was eagerly sought and highly valued. His views on the city improvement scheme, as conveyed to Lord Provost Chambers and Mr. David Cousin, city architect, along with his letters which appeared in the "Scotsman" at the time, greatly facilitated the accomplishment of this great sanitary improvement, while amongst other local works his firm designed and carried out the Edinburgh and Leith sewerage scheme, and the widening of the North Bridge.

In addition to many Papers principally on engineering and cognate subjects read before different societies, Mr. Stevenson found time, amid the exacting calls of his profession, to write several books which have taken a permanent place in engineering literature, such as "The Application of Marine Surveying and Hydrometry to the Practice of Civil Engineering," "Reclamation and Protection of Agricultural Land," "The Principles and Practice of Canal and River Engineering." He also wrote several articles for the last and present editions of the "Encyclopædia Britannica," among which may be noted "Canal," "Cofferdam," "Diving," and "Dredging." He was also the author of "Our Lighthouses," being two articles written for his old friend Dr. Norman Macleod, while editor of "Good Words," and subsequently published by Messrs. Black; and of the "Life of Robert Stevenson," published in 1878.

Mr. Stevenson was elected a Fellow of the Royal Society of

Edinburgh in 1844, and he subsequently acted as a member of Council and one of its Vice-Presidents. He was elected a Member of the Institution in 1844, and acted as a Member of Council from 1877 till 1883, when he retired on account of bad health; he was also a Member of the Société des Ingénieurs Civils, Paris, and of other learned Societies.

He was consulting engineer to the Highland and Agricultural Society, and engineer to the Convention of Royal Burghs of Scotland. In the affairs of the former he took a lively interest, especially as regards improvements in agricultural implements, and contributed several papers and reports to their Transactions, notably one on the reclamation of land, and another on the relative merits of the different systems of steam ploughing. He took a warm interest in the better endowment of the Chairs in the University of Edinburgh, and was mainly instrumental in founding the Glover Divinity Fellowship. He was a great lover of art in all its branches, and had formed a somewhat valuable collection of etchings and engravings begun when a boy at the High School.

He was a man of sound judgment, utterly devoid of ostentation, kind, open, and easily accessible. Since 1883, owing to failing health he was practically laid aside from work, but had gone as was his wont to North Berwick for summer quarters, where he was seized with an apoplectic shock, and died on the 17th of July, 1886, in his seventy-second year.

WILLIAM BURTON WADE was the second son of the Rev. Charles Gregory Wade, for many years rector of Hanwood, Shropshire, and of his wife Hannah Maria Burton, daughter of Robert Burton, both of good old Shropshire families.

The Rev. Mr. Wade was one of the commissioners of the Holyhead Road, on which Telford and Macneill were then engaged, and this no doubt influenced the choice of a profession for his second son. Burton Wade, as he was always called, was born at Hanwood on the 23rd of October, 1832, was educated first at home, then at Rossall School, and, after three years' study at the Putney College of Civil Engineers, young Wade was articled to the late Samuel Clegg, M. Inst. C.E., who was engaged on gas and sewerage works, railways, and some harbour and canal projects.

In the year 1855, finding it difficult to obtain professional employment in England, Burton Wade sailed for Sydney, N.S.W., and immediately on his arrival was engaged by the late Sir

Gilbert Elliott, Chief Commissioner for the Municipal Government of Sydney, as assistant to the late Mr. Edward Bell, M. Inst. C.E., then City Engineer. Mr. Wade was at once employed to assist in superintending the large sewerage-works, and in the preparation, under Mr. Bell, of the designs for the Sydney Waterworks, which he afterwards helped to carry out. Mr. Wade remained as Mr. Bell's chief-assistant under the re-established corporation after the abolition of the Commissions, and left on completion of the engines, main and reservoirs. During the latter part of this service Mr. Wade, associated with a friend, obtained the first prize of £250 in a competition for the best designs for the sewerage of Launceston, Tasmania. The referee, the late Sir William Denison, K.C.B., R.E., Assoc. Inst. C.E., then Governor of New South Wales, pronounced the design as the best of the fifteen sent in, stating: "I have no hesitation in awarding the first prize. The general scheme is well adapted to the present as well as future wants. All the details are well worked out, and the estimates carefully framed." On leaving the city works, Mr. Wade, in February 1859, was engaged by Mr. Whitton, M. Inst. C.E., Engineer-in-Chief for railways, New South Wales, in preparing working surveys, and then in charge of the works from Black Creek to Singleton. Mr. Wade was continued in that capacity as each extension was let until June, 1872, when the line was completed to Murrurundi, having charge during the latter part of this time of the trial-surveys, of the northern extensions to Narrabri and Tenterfield respectively. Mr. Wade was next removed to Bathurst as Resident Engineer of the extensions of the western line, from Raglan to Bathurst, and thence through Orange to Dubbo, including the construction of two iron bridges, one consisting of three spans of 150 feet each over the Macquarie river, at Bathurst, and another, of four spans each of 150 feet, at Wellington; having completed up to that point a total of 193 miles of railway on the northern and western lines.

In 1879, the great increase in work rendered it necessary that Mr. Whitton should have an able confidential assistant to inspect in his stead, from time to time, all the railway-works in the colony. For this duty he selected Mr. Wade, to whom was given the general superintendence of the extensions; Yass to Albury, Junee to Hay and Jerilderie, Wellington to Bourke, Wallerawang to Mudgee Quirindi to Narrabri, Tamworth to Tenterfield and Sydney towards Illawarra, on which works of considerable magnitude have been carried out, namely, iron bridges over the Macquarie at Dubbo, two iron bridges over the Murrumbidgee at Wagga and Narran-

dera, one over George's river at Como, near Sydney, one over the Murray, at Albury, one over the Peel at Tamworth, and one over the MacDonald near Bendemeer, with several smaller bridges, all the stations, buildings, watering appliances, &c.

Mr. Whitton had the most implicit reliance on Mr. Wade's judgment and integrity, and when exertion and exposure in the hot climates and seasons had injured his health Mr. Whitton was most considerate, and by his permission Mr. Wade was enabled to visit England in the year 1885, in hope of improvement; but the trip was attended by only a slight temporary rally, and soon after his return to the colony, on the very day of his re-taking possession of his own house, at Ashfield, he was seized with an attack which affected his speech, and he never from that day resumed duty. On the 12th of July, 1886, he succumbed to a final seizure of paralysis, after being six days speechless, though quite sensible.

Mr. Wade was above all things a true English gentleman, exceedingly fond of field sports, in which the arduous nature of his occupations seldom permitted him to indulge; fond of reading, he kept himself well posted in the literature of the day; he was gifted with a keen sense of humour, and occasionally indulged in a good-natured sarcasm or quaint application of well-known quotations to current events; under a blunt and straightforward manner and speech he concealed a genial, generous and feeling disposition. He possessed much tact, and a most happy way of managing both contractors and workmen, over whom he exercised the utmost strictness without once having a personal difference. Those who disagreed most with him on official business were the first to express regard for his loss and to pay respect to his memory. He was held in the highest estimation by his professional brethren in the colony and by none more so than the chief of his department, and while a general favourite his intimate friendship was reserved for a few, but those who knew him best and longest most appreciated his good qualities. Notwithstanding the position held by Mr. Wade for so many years and the important duties performed by him, he was much less generally known than many men of inferior worth. Shrinking from ordinary publicity, he made no effort to attract public notice, but was satisfied with the conviction of a faithful performance of his duty and a sturdy and loyal adherence to his chief, Mr. Whitton, whose good opinion he justly valued.

Had Mr. Wade's served under the Government of India his death would have been announced and his services recapitulated and acknowledged by order in Council; but being engaged under

the Colonial Government, the only official expression of regret or acknowledgment of his services was a kind and sympathetic private note from Mr. Whitton to Mrs. Wade.

He was elected a Member of the Institution on the 4th of April, 1865, but absence in the colony prevented his taking an active part in the proceedings.

JOHN EDWARD CATTON was born at Aberdour, Fife, on the 17th of July, 1853, and was mainly educated at the Dollar Academy, where he particularly distinguished himself in mathematics, being medallist in 1870. After leaving school, he was for some time a pupil in the office of the Chief Engineer of the North British Railway, also attending the lectures at Edinburgh University. In September 1872 he entered the Royal Indian Engineering College, at Cooper's Hill. Here the distinction he had acquired at Dollar was continued, he being accounted one of the most promising students of his year; so much so, in fact, that whereas the usual term of residence is three years, Mr. Catton was permitted to compete at the Final Examination in 1874, and passed out after only two years' residence, winning the Baker Scholarship in applied mechanics. Being appointed an Assistant Engineer in the Indian Public Works Department, Mr. Catton arrived in Bombay on the 21st of November 1874, and was posted to the Punjab Irrigation Branch, joining the Western Jumna Canal on the 10th of December of that year. He was employed principally as Resident Engineer in charge of the head-works and main line of the canal, on the careful supervision and maintenance of which the success of the entire system depends. Between December 1875 and October 1877 he held the post of Personal Assistant to the Superintending Engineer of that circle of irrigation; and in August 1880 was transferred as a temporary measure to officiate as Assistant to the Chief Engineer and Under Secretary to the Punjab Government in the Irrigation Branch. On being relieved by the permanent incumbent, Mr. Catton was sent on special duty to the Shahpoor District to give professional advice to the local civil officers regarding the best method of improving the system of inundation-canals in their charge; and on his return received the thanks of His Honour the Lieutenant-Governor for his services. He was then transferred to the 2nd Division of the Baree Doab Canal, of which he held executive charge for a short time, after which he was again posted to the office of the Chief Engineer as Under

Secretary to the Punjab Government, which appointment he continued to hold until he left India on furlough in April 1885.

Mr. Catton passed the Higher Standard examination in both the Hindustani and the Punjabi languages, and was a magistrate under the Northern India Canal and Drainage Act. While on furlough he was appointed to supervise the practical training of the students of the Cooper's Hill College, and was so engaged at the time of his death, which occurred suddenly at Braemar, N.B., on the 17th of August 1886, when only thirty-three years of age.

Mr. Catton was one of the most rising of the younger officers of the Department, and thought highly of by all under whom he served, and his untimely death caused universal regret among his familiars both in India and at Cooper's Hill. He was elected an Associate Member of the Institution on the 7th of December, 1880.

WILLIAM HENRY COCK was born at Swansea on the 10th December 1833, and was educated in that town until he was about fifteen. In the year 1850 he was articled to Mr. Hibbert, and was engaged in various engineering works—surveys of Chichester and Langstone Harbours; land-reclamation at Hayling; and, under Mr. Wyndham Tarn, A.R.I.B.A., he was employed to superintend the erection of several extensive buildings in Yorkshire; and was afterwards engaged on surveys, &c., for waterwork schemes at Bradford and Leeds, Barnsley drainage, &c. For nearly two years he was employed on the Newport drainage-works, and on railway surveys under Mr. Alfred Williams, M. Inst. C.E. In 1859 he went out to Rio de Janeiro as assistant to the late Mr. W. G. Ginty, M. Inst. C.E., having special charge of the gasworks, and assisting in the construction of a canal from the harbour to the gasworks; tramway-lines in Rio, &c. In 1862 he was employed by Baron de Mauá to explore and report upon the feasibility of the navigation of the Salado river (Argentine States), and was subsequently engaged to effect the canalization of this river from Matará to Fort Bracho; but owing to financial and political difficulties the scheme was not carried out. A series of letters describing the Salado, and the nature of the work to be undertaken, were published in the Buenos Ayres papers at the time, and reflect great credit upon him for the boldness and originality of his scheme. In 1865 Mr. Cock took charge of the Montevideo Gasworks, and during the seven years of his management he more than doubled the capacity of the works, and constructed the Mauá-graving dock, 226 feet

in length, cut for the most part out of solid rock, and having machinery capable of pumping it dry in four hours. In 1872 he was engaged by Messrs. Jackson and Cibils, of Montevideo, to design and superintend the construction of a graving-dock, 450 feet in length, on the western side of Montevideo Bay, a work which was successfully carried out under his immediate supervision, without the aid of a contractor. He also designed, in consultation with Mr. Charles Neate, M. Inst. C.E., some further works in connection with the graving-dock, consisting of a basin and piers for the accommodation of the coaling-trade of the port; but owing to the depressed state of trade in general, the owners have not thought it advisable to carry out these additional works. In 1882 he was appointed by the Argentine Government Engineer to the Arsenal, when he went to reside in Buenos Ayres. He had almost completed the design of a large dock and basin for the accommodation of the Argentine navy, when he was struck down by paralysis, from which he never recovered sufficiently to resume his duties at the Arsenal, and he died on the 27th of May, 1886.

Mr. Cock earned the esteem and friendship of all who knew him, and leaves behind the reputation of being an accomplished engineer, a man of incorruptible probity, and of singular modesty and urbanity. He was elected an Associate Member of the Institution on the 4th of February, 1868.

CHARLES WILLIAM MORGAN, the youngest son of John Robley Morgan, of her Majesty's Bombay Civil Service, was born on the 7th of December, 1859, at Tannah, India. He was educated first at private schools at Brighton; and he afterwards proceeded to Germany, where he remained three years, studying subjects connected with his intended profession of a civil engineer, for which he had an early predilection. In the year 1876 he entered the Glasgow University and remained there three years attending lectures on civil engineering, mechanics, &c., in which subjects he passed creditable examinations, intending at some future time to take his degree as Bachelor of Science.

He became an articled pupil to Mr. Shelford, M. Inst. C.E., in September 1880, and, after a brief period of office routine, was placed in charge of the works in connection with the construction of the Southwark and Deptford tramways. In July 1881 he was appointed by Messrs. Shelford and Bohn, MM. Inst. C.E., Assistant District Engineer, on the extensive works of the Hull and Barnsley

Railway, of which they were joint Engineers, and in this capacity gave such excellent proof of ability that he was subsequently entrusted with the responsible supervision of a district, the works of which he carried through to completion. On the termination of his engagement with Mr. Shelford, Mr. Morgan accepted employment under Sir John Coode, V.-P. Inst. C.E., at the Peterhead Harbour works, a post which he resigned in November 1885, in order to take up an appointment on the staff of the Indian Midland Railway Company; and at the time of his very sudden death (due to heat apoplexy) on the 27th of May, 1886, at Gwalior, was in camp engaged on the field-work connected with that railway.

Mr. Morgan was in his work energetic and persevering, and during his brief professional career gave excellent promise of a most successful future. He possessed a rare amount of tact and shrewdness combined with a courteous and genial manner which procured him many friends, of whom those privileged to enjoy his close personal acquaintance will ever treasure the memory. He was elected an Associate Member of the Institution on the 1st of December, 1885.

GEORGE JOPE YEO was born on the 24th of September, 1844, and received his early education at St. John's College, Hurstpierpoint, under the Rev. Dr. Lowe. In 1861 he was apprenticed for five years to Mr. Lees, then manager of the Lancashire and Yorkshire Railway Company's locomotive works at Bury, acquiring a general knowledge of mechanical engineering under very competent and skilled supervision. He was a steady and persevering youth, and by his courteous manners, and attention to all the details of his duties, won both the esteem and good-will of manager and operatives. His evenings were spent generally in mechanical drawing, and in other means of self-improvement. When his term of apprenticeship had expired, he engaged himself to Messrs. Bland, of Bury, and served there for two years, chiefly in the making and erection of beam and horizontal steam-engines. Thence he went to the Worcester Engine-Works, under the late Messrs. Edward Wilson, M. Inst. C.E., and Alexander Allen, ostensibly as a draughtsman, but was employed in various departments, having for about two years charge of a number of workmen in erecting iron roofs and other work on the Metropolitan Railway. He next became Assistant-Engineer of the Cheltenham Gasworks, under the late Mr. Esson, mastering the details of that business

so as to make himself fit for a manager's position. In 1871 Mr. Yeo went to China as Assistant Manager of the Shanghai Gas-works, and two years later, on the resignation of Mr. Mead, was appointed Engineer and Secretary. In this capacity he entirely reconstructed and extended the works. He continued to discharge his duties to the entire satisfaction of the Company for nearly fifteen years, till, in 1884, his health broke down. He then came to England and was under medical treatment for twelve months, recovering sufficiently to return to China; but it was only to settle all the Company's affairs, and then to end, on the 23rd of June 1886, a useful and a well-spent life. Mr. F. B. Forbes, the late Chairman of the Shanghai Gas Company, entertained a very high opinion of Mr. Yeo's capabilities, and states that his management "resulted not only in a notable economy in the cost of producing gas, but in a marked improvement of its quality." Mr. Yeo's chief characteristics were his self-reliance, energy, and unflagging industry. Above all these, he was a man of high Christian principle, and the very soul of honour.

He was elected an Associate Member of the Institution on the 3rd of February, 1885.

FREDERICK WILLIAM HARTLEY was born in Westminster in 1829. Though self-educated, he was a remarkably well-informed man, and a fluent speaker. His talents and commercial aptitude were of such a nature that, had he entered into business on his own account (and opportunities were not lacking), it is most probable that he would have realized a considerable fortune. But he was a man who placed duty before every other consideration; and having accepted the position of manager of the gas-appliance business of Alexander Wright and Co., of Millbank Street, Westminster, he remained unswervingly faithful to the trust reposed in him. This trust, together with the care of the widow and children, was confided to him by the late Alexander Wright, his first employer, on his deathbed. From the year 1859 till the close of his life, Mr. Hartley devoted all his energies and talents to the discharge of the duty he had undertaken, and it is only just to say that, if it had been his own business, he could not have done more. It is not therefore surprising that every one connected with the large and wide-spread industry of gas held him in high esteem; and his varied knowledge, always at the service of those who asked information from him, together with his great ability and amiable disposition, made lasting friends of those who had the pleasure of his acquaintance. His honourable and upright conduct in the

transaction of business was as much appreciated by his rivals as by his friends. He died literally in harness, on the 17th of October, 1885, suddenly, but painlessly, from disease of the heart. His funeral at Brompton Cemetery was attended by a large number of professional friends.

Mr. Hartley was many years ago elected by acclamation an Honorary Member of the Gas Institute; and this, the highest testimony of his worth, accorded to him by those who knew his work, was highly valued by him. His work was so varied that it is difficult within reasonable limits to describe it. He wrote frequently on scientific subjects connected with gas, and published, amongst other works, a most useful text-book on Gas-Measurement and the testing of Gas-meters. In this department of business he was a great authority, and he was able to afford valuable assistance to the Standards Department of the Board of Trade. He also published a useful work on the Analysis of Gas. At the Inventions Exhibition of London, in 1885, he exhibited a complete and interesting collection of the scientific apparatus which he had either invented or improved. Amongst others, was an improvement on Thompson's calorimeter for demonstrating the heating power of coal; and a new form of Photometer, which he had designed to combine the uses of several distinct instruments, used in ascertaining the photometrical value of different means of producing artificial light. In the year 1883 he was engaged, in cooperation with Mr. Charles Heisch, in carrying out an important series of experiments for the Gas Institute on the question of Standards of Light; and he also made an exhaustive series of tests of gas-burners and stoves for the Committee of the Crystal Palace Gas and Electric Exhibition in 1882.

Mr. Hartley was elected an Associate Member of the Institution on the 1st of April, 1873.

SIR JOHN KELK, Bart., of Tedworth, in the county of Hants, died on the 12th September, 1886. He was one of those men who, without any adventitious aid from powerful or wealthy connections, or from any extraordinary good fortune, or by any commanding abilities or eloquence, have, by a combination of industry, intelligence and integrity (to use the language of Dr. Johnson) "been enabled to find or to make their way to employment, riches, and distinction." He was born in London on the 16th of February, 1816, of parents in the middle rank of life, and, after a good com-

mercial education, was apprenticed to Thomas Cubitt, the builder, who had then commenced the struggle which, in his case, was pre-eminently successful, of raising his trade to the dignity of a profession. A better school could not have been chosen for young Kelk. On the termination of his apprenticeship he entered into partnership as a builder with a Mr. Newton, who had for many years carried on, in Margaret Street, Westminster, a respectable but not very extensive business, from which, however, he retired in the year 1845, leaving his more energetic partner at liberty greatly to extend it, by availing himself of the knowledge of affairs which he had rapidly acquired. This he did by taking alone, or in partnership with more experienced persons, contracts for large railway and other public works. He was thus associated at times with Mr. Brassey, Messrs. Peto and Betts, and others, and speedily took a high position in the commercial world.

This enabled him, shortly after the close of the Great Exhibition of 1851, to afford material assistance to the Commissioners for that Exhibition in the disposal of the large amount of profit which arose from it. At the close of the undertaking there remained a surplus exceeding £150,000, and in the discharge of their duties the Commissioners determined to devote this amount (in conjunction with Government, which was to contribute a like amount) for the purchase of land in the metropolis available for the erection of buildings to be used for national purposes in connection mainly with science and art. It happened that, at this particular time, there was in the market the valuable Gore House estate, situate at Kensington, nearly opposite to the Exhibition building, and consisting of about 21½ acres. Had it transpired that the Exhibition Commissioners wished to purchase, the price asked for the estate would have been greatly increased, and it was therefore determined to secure the services of some capitalist to treat for it who might reasonably be supposed to require it for his own purposes. On the introduction of Mr. (afterwards Sir Wentworth) Dilke, one of the Commissioners, Mr. Kelk undertook this duty, entered into the requisite negotiation and signed the contract for purchase, without the vendors of the estate having the slightest idea for whom he was purchasing or of the object which he had in view, beyond the fact of his being known to be an enterprising and extensive builder. The price of this property was £60,000, and it formed the nucleus for the larger estate at South Kensington on which so many public buildings stand. For the assistance thus given Mr. Kelk neither asked, received, nor expected any pecuniary

remuneration whatever. In the second Report of the Commission for the Exhibition of 1851 to the Home Secretary will be found a more detailed statement of this transaction, with a due recognition of Mr. Kelk's services.

The good understanding thus established between Mr. Kelk and the Commissioners doubtless led to his tendering, in conjunction with Messrs. Lucas Brothers, for the buildings used for the Exhibition of 1862. This tender was accepted, and the contracts for the buildings were completed by the combined firm. Unfortunately the success which attended the previous undertaking was not extended to that of 1862, and at its close there was a considerable deficit to be made up. The Commissioners had acted under a formal guarantee, signed by many noblemen and gentlemen, including, in fact, most of the important public men of the day, and, it is needless to say, Mr. Kelk himself. A call upon the guarantors would have doubtless met the difficulty; it was, however, considered by those who had been most influential in its promotion, particularly Mr. Kelk himself, that such a step would be a national discredit.

On the 16th September, 1862, Mr. Kelk wrote to Earl Granville, the Chairman of the Commissioners, in which he said: "I am induced to address your lordship in consequence of the conversation I had yesterday with Her Majesty's Commissioners respecting the proposed alteration of the terms with the contractors for the Exhibition building. It may be that this arrangement will not be sufficient fully to relieve the guarantors, and upon closing the accounts it may be found that a responsibility still rests upon them. As I feel this would be a very sad termination to a great national undertaking, and perhaps fatal to the principle of International Exhibitions, I am willing to offer some further assistance, and shall be prepared to guarantee a sum not exceeding £15,000, if such sum will entirely free the guarantors. I submit this offer to your lordship as Chairman of Her Majesty's Commissioners for the Exhibition." In the sequel Mr. Kelk sent a cheque for the £15,000 thus patriotically offered. Of this a sum of £4,000 was subsequently returned as not being required on finally closing the accounts.

Another most important work, and one in which Mr. Kelk took an equal interest, was committed to his charge at a somewhat later period, viz., in the year 1864, when he had the high honour of being nominated and selected as the fit and proper person under Sir Gilbert Scott, the Architect, to carry out the works connected with the erection in Hyde Park of the Memorial to the Prince

Consort. This work he undertook and carried out on the express condition stipulated for by himself, that personally he should derive from it no pecuniary benefit whatever, directly or indirectly. This condition was strictly adhered to.

In conjunction with Messrs. Aird, Mr. Kelk constructed the Millwall Docks. But of all the public works upon which Mr. Kelk was engaged, the one upon which he had the most cause to pride and congratulate himself was the completion of the Victoria Station and Pimlico Railway. The idea of bringing the Southern and Eastern Railways immediately into the Metropolis, by the building of a bridge over the Thames at Charing Cross or some other convenient locality, had long been discussed in railway circles; and it was well known that Mr. Schuster, then Chairman of the Brighton Company, much wished to advance the Brighton Railway from the south side of London Bridge to Charing Cross by crossing the Thames at Hungerford, but that he was afraid of the expense. Mr. Kelk, who had now had considerable experience in railway business, having on former occasions worked under Mr. (now Sir John) Fowler as Engineer and with Mr. (now Sir Henry) Hunt as Surveyor, and had acquired considerable financial as well as engineering and local knowledge connected with railways, conceived the idea of bringing the Brighton Railway and also the East Kent Railway, now the London, Chatham and Dover (which was then wholly without a London station), into the most fashionable part of the Metropolis, viz., a locality near Buckingham Palace. This was accomplished by using for a railway the Grosvenor Canal, throwing a bridge over the Thames at Battersea, and making a short line to join the Crystal Palace Railway, the terminus of which was situate near to the river on the Surrey side. In this way not only the Brighton and the East Kent Railway but all the other southern and eastern railways, and, in fact, the Great Western Railway also, were brought into connection with a terminus at Victoria. The Act of Parliament authorizing the construction of the Victoria Station and Pimlico Railway received the Royal Assent on the 23rd of July, 1858, and the Victoria Station was opened in October 1860.

The association with Mr. Fowler thus commenced lasted through the remainder of Sir John Kelk's business life. He enlarged the Farringdon Street Station of the Metropolitan Railway in 1863, and was successively occupied, either singly, or in conjunction with partners, on works for that line and its extension, the Metropolitan District, until 1871. He also, between the

years 1866 and 1869, built the great Smithfield Goods Depôt and Meat Market for the Corporation of London, the Great Western, and the Metropolitan Railway Companies.

At the close of his professional career, however, he met with a reverse of fortune in connection with an undertaking from which he had anticipated not only fair profits but a considerable degree of credit, by extending for the public benefit the stock of harmless amusement. This object it was fully expected might be effected by establishing at the north-east of London a place of entertainment on a plan somewhat similar to that which the residents of the south of the river enjoy from the Crystal Palace, but even on a larger scale, viz., the construction and working of the too well-known Alexandra Palace. This magnificent building was burnt to the ground in June 1873 within a few days after its opening. The expenses of the purchase of the land, and the erection of the structure and other incidental expenses connected with the undertaking, had been paid at first in thirds by the London Financial Association, Messrs. Kelk and Lucas, and Mr. Rodocanachi, but after the retirement of the last-named gentleman, by the Association and Messrs. Kelk and Lucas in moieties. The Palace was rebuilt, but proved to be an utter failure; the loss incurred was in itself a very heavy one, but this was not the worst; certain dissatisfied shareholders in the Financial Association having displaced the Directors who had acted in the conduct of the business, caused an action to be brought in the name of the Association against their co-adventurers and the ex-Directors, the charges against the ex-Directors being founded mainly upon the allegation of their having acted *ultra vires* in embarking in the undertaking, but against Messrs. Kelk and Lucas they were based upon matters connected with them as contractors for the works. In giving judgment the Vice-Chancellor declared the action to be wholly without foundation, and dismissed it with the fullest amount of costs which he could inflict upon the plaintiffs.

Sir John Kelk was in politics a Conservative, and sat in the House of Commons as Member for the Borough of Harwich from July 1865 to November 1868, in conjunction with Colonel Jarvis, but when by the Reform Bill of 1867 the borough was deprived of the right to return a second member, he gave place to his colleague, who had first represented the borough, and he did not again offer himself for election by any other constituency.

Sir John was elected an Associate of the Institution on the 5th of February, 1861.

JOHN PEAKE KNIGHT was born in Nottingham on the 13th of January, 1828, and was educated at the local Grammar School, the Rev. W. Butler being then head master.

He left school in 1841, and commenced his business life in the Parcel- and Telegraph-Offices of the Midland Railway at Derby Station, where his elder brothers, William and Sam, were likewise then employed. He was also for a short time engaged with Mr. Peter Clarke on the York and North Midland line at York Station, acting in the capacity of private secretary to that gentleman. When Mr. Peter Clarke was appointed General Manager of the Brighton Railway, he sent for his former assistant, in whose welfare he had always taken a friendly interest. In this way Mr. J. P. Knight first became connected with the Brighton Company, taking up his duties in the Audit Offices, which were then at Brighton, in the year 1846. In 1853 he left the Brighton Company, and was engaged by its neighbour the South Eastern, whose London terminus was then at Bricklayers Arms. He was shortly afterwards appointed Superintendent of that line, and held the post until 1869. In the latter year Mr. George Hawkins, the Brighton Company's Traffic-Manager, retired, and Mr. Knight was appointed his successor. He had not long been Traffic-Manager before the Directors, being so well satisfied with him, made him their General Manager, which position he retained until the day of his death.

Enjoying the thorough confidence of his Directors, and having full scope for carrying out his enterprising and far-seeing plans for the development and improvement of the line, Mr. Knight succeeded in making the Brighton railway one of the most popular in the kingdom, with a deserved reputation for careful working and immunity from accident. He was more especially known by the general public for his skill and smartness in organising provision for the pressure of traffic on the occasion of popular holidays such as those made by statute and occurring four times a year; gatherings at the Crystal Palace; Volunteer Reviews; and above all, the Derby Day. In respect of the latter it was his custom some days in advance of the great race-meeting to make a special survey of the line and rolling-stock, minutely inspecting the track, and making sure that everything was well prepared for the great strain shortly to be put upon it.

For the material improvement of the line under his charge, Mr. Knight worked unceasingly. He was instrumental in the adoption of the interlocking of signals, and the block system. In the years 1877 and 1878, he went very fully into the necessity

for providing passenger-trains with an efficient continuous brake, and made extensive and exhaustive inquiries with respect to the merits of the various kinds then in use, which led to the adoption by the Brighton Company of the Westinghouse automatic brake, with which the whole of its trains are now fully equipped. He in 1877 introduced Pullman Cars, which have been very popular with the travelling public on the line, so much so that the number of cars has from time to time been increased. It may also be mentioned that in December, 1881, a novel feature was introduced on the Brighton line, namely, a train composed entirely of "Pullmans," consisting of parlour-drawing-room- restaurant- and smoking-cars, all communicating with each other, enabling passengers to pass through the entire length of the train. This train still runs between London and Brighton, two or three ordinary first class carriages having recently been attached to it. Through the instrumentality of Mr. Knight the system of lighting carriages by electric accumulators was first introduced in England in the Pullman-car train referred to, and it has been in operation and working satisfactorily in that train ever since. He also initiated, about 1884, the system of lighting carriages by electricity generated from the axles of the brake-van, described by his colleague, Mr. Stroudley, M. Inst. C.E.[1] This system is now at work in several trains. After the Paris International Exhibition of 1878, Mr. Knight received the distinction and decoration of the Legion of Honour from the French Government. He also received many other distinctive marks of honour from Royal and distinguished personages. The Crown Prince of Germany forwarded, through Count Munster, in the year 1881, a bronze bust of himself for Mr. Knight's acceptance, in acknowledgment of the many kind attentions shown by him to their Royal and Imperial Highnesses the Crown Prince and Princess during their stay in England in the summer of that year. Mr. Knight had conferred upon him by the Emperor and Empress of Austria the Order of the Iron Cross.

He had the special privilege of making all the arrangements in connection with the reception of His Royal Highness the Prince of Wales, on his return from India in the year 1876, for which Mr. Knight received one of the copies of the few commemoration medals His Royal Highness had struck to mark the event. Mr. Knight also received, in the year 1876, at the hands of His Royal Highness the Prince of Wales two fine portraits

[1] Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 329.

of their Royal Highnesses the Prince and Princess of Wales, accompanied by a letter from Lieut.-Colonel Arthur Ellis, expressing the Prince's appreciation of his constant readiness to secure punctuality whenever the Prince has had occasion to travel on the railway under Mr. Knight's charge.

Queen Marie Amélie likewise presented to him, when he was in the service of the South Eastern Railway Company, a valuable ring, and also a handsome bracelet for Mrs. Knight.

Mr. Knight was elected an Associate of the Institution on the 7th of May, 1872, and was also a Lieutenant-Colonel in the "Engineer and Railway Volunteer Staff Corps."

Mr. Knight for many years enjoyed uninterrupted good health, but on the 18th of March, 1886, he was seized with a fit of apoplexy, though by the skilful and unremitting exertions of his physicians, he made tolerable progress towards convalescence. It was manifest, however, to the Directors that when Mr. Knight returned to his duties on the 22nd of May following he had not by any means recovered his usual health. He was present at the Brighton Company's half-yearly meeting, on the 21st of July, 1886, when the chairman congratulated the shareholders upon the improvement in Mr. Knight's health, and upon his being present on that occasion. On the following day Mr. Knight attended at his office, and was engaged with Mr. Humphriss, his chief assistant, in the transaction of his duties, until the afternoon. Immediately afterwards he left town on a short visit to some friends at Chigwell, and about 9 o'clock in the evening of the same day he had another apoplectic fit, falling at the dinner table, but remaining conscious for about two hours afterwards, and exchanging conversation with Mrs. Knight and the physicians in attendance on him. His illness terminated fatally on the morning of the following day, in the fifty-ninth year of his age. On the 28th of July he was interred at Brompton Cemetery, in the presence of the Directors and of a great concourse of his associates of the Brighton railway, as well as of representatives from all the leading railway companies in the kingdom, and of several foreign ones with which his own line had been connected.

ASTLEY PASTON PRICE, the third son of the late Dr. Price, of Margate, was born in the year 1826. He was educated at Margate, and having a considerable taste for chemistry he was, after leaving school, placed by his father with a firm of manufacturing chemists

in London. With this firm he remained for about three years, during which time he attended the chemical classes at University College, where he was a favourite pupil of Professor Graham, late Master of the Mint. This acquaintance ripened into a close intimacy and a lasting friendship. He then went to Giessen, where he studied chemistry under Liebig and took the Ph.D. degree. He subsequently studied at Paris for some years under Pelouze, whose personal friendship he also acquired.

Dr. Price then returned to England, and became Assistant to Dr. Hoffmann at the Royal College of Chemistry, afterwards receiving an appointment in the School of Mines. During this portion of his career he not only attained a very extended knowledge of chemistry, but became the associate and friend of many of the leading chemists of the day, both at home and abroad. Many of his fellow-students at Giessen and Paris will bear witness to the kindness they invariably received from Dr. Price on their visits to this country. His linguistic attainments, as well as his chemical talents, were always at their disposal, and the advantages they derived from his intimate acquaintance with Graham, Hoffmann, Percy, and others, are still remembered by his foreign friends. During the time Dr. Price was at the College of Chemistry and the School of Mines, he lost none of the opportunities open to him of visiting the large chemical manufacturing works of this country, and few men of his age possessed so varied and extensive a knowledge of practical and technical chemistry as he did. During this period of his life he was also intimately associated with Mr. (now Sir Frederick) Abel, F.R.S.; Dr. Odling, F.R.S., now the Oxford Professor of Chemistry, and many rising chemists whose reputations have since become European. The acquaintances then made lasted throughout his life. In the year 1851 Dr. Price accepted the position of chemist to the silver-works of Messrs. Dillwyn and Co, of Swansea, and took up his residence in Swansea for about six years. On his return from Swansea, Dr. Price commenced to practice as a consulting-chemist in London, and was in this way consulted by many of the largest firms in the kingdom. Although he invariably declined to give evidence in Court as a chemical expert, he had an extensive practice in chemical patent-cases. Amongst others he had the conduct of the chemical part of the great case of Young *v.* Fernie, in which the validity of Mr. Young's patent for the manufacture of Paraffin oil was maintained. Dr. Price was possessed of great inventive talent, and the patent lists for the last thirty-six years contain the records of his many inventions relating to the manu-

facture of sugar, the treatment of metals and ores, the distillation of carbonaceous materials, the treatment of sewage, &c. For the last ten years of his life he suffered much from ill-health, and was entirely prevented from any active prosecution of his profession; his interest in chemical science, and in the progress of chemical industry, was however maintained to the last. In private life few men possessed so large a circle of friends, to whom his versatile talents, and his impulsively generous and thoroughly unselfish character universally endeared him.

Dr. Price died at Margate on the 3rd of April, 1886. He was one of the earliest Fellows of the Chemical Society, and was elected an Associate of the Institution on the 23rd of May, 1865.

⁂ The following deaths have occurred since the 12th of September last, in addition to those included in the foregoing notices:—

Members.

DIRKS, JUSTUS.
EVANS, WALTON WHITE.
GREEN, CHARLES FREDERIC.
HOMERSHAM, SAMUEL COLLETT.
PALMER, JOHN BROUGH.
RICH, WILLIAM EDMUND.
STEELL, JOHN.
VANSITTART, JOHN PENNEFATHER.
WOOD, HENRY.

Associate Members.

ELLIS, THOMAS CHARLES.
EWING, LUDOVIC STEWART RUDOLPH.

Associates.

GOODWYN, *General* HENRY, R.E.
MILROY, JOHN.
PIM, *Rear-Adm.* BEDFORD CLAPPERTON TREVELLION.

Information respecting the careers and leading characteristics of any of the above is solicited, to aid in the preparation of future Obituary Notices.—SEC. INST. C.E. *Dec.* 31, 1886.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

The Proceedings of the German Cement-Makers' Association.

(Protokoll der Verhandlungen des Vereins deutscher Cement-Fabrikanten und der Section für Cement des deutschen Vereins für Fabrikation von Ziegeln, Thonwaaren, Kalk und Cement, Berlin, 1886.)

The meeting of this association, which represents an anuual production of 910,000 tons of cement, was held at Berlin on the 26th and 27th of February, 1886. Several questions relating to the manufacture and testing of cement were discussed, and a revised set of standard rules adopted. Among other experiments reported to the association were a series of tests made with twelve different cements by three different persons. The cements were bought in the open market, and subjected to a variety of tests, including the tensile and crushing tests of different sand-mixtures. A Table is given containing the results obtained. The quickest cement set in three-quarters of an hour, and the slowest in thirteen hours. The coarsest sample left a residue of 49 per cent. upon a sieve of 32,256 meshes per square inch (5,000 meshes per square centimetre), while the finest left a residue of 20 per cent. upon the same sieve. The highest specific gravity noted was 3·137, the lowest 2·976. One of the cements was adulterated with slag, and was very deficient in strength. In the case of briquettes composed of neat cement and made by hand, the highest tensile strength was 702·6 lbs. per square inch (49·4 kilograms per square centimetre), and the lowest 323·6 lbs. per square inch (22·75 kilograms per square centimetre) in twenty-eight days. Tensile tests were made with briquettes composed of a mixture of one part of cement to three parts sand, some of the briquettes being made by hand and some by machine. In most cases the hand-made briquettes showed a slight increase of strength in twenty-eight days as compared with the machine-made. The highest tensile strength obtained with this mixture after twenty-eight days' immersion in water was 333·5 lbs. per square inch (23·45 kilograms per square centimetre), the lowest 94·75 lbs. per square inch (6·66 kilograms per square centimetre). Crushing tests of the three to one mixture were also made; here the maximum was 3348·6 lbs. per square inch (235·43 kilograms per square centimetre), and the minimum 574·6 lbs. per square inch (40·4 kilograms per square centimetre).

In consequence of the results obtained, it was resolved to make

the crushing test the decisive one. It was found that when the briquettes were exposed to the air for fourteen days, after having been immersed in water for a like period, the strength increased 50 per cent. as compared with briquettes which remained under water the whole of the twenty-eight days. The tests made with neat cement showed that the figures obtained did not allow a comparison to be drawn between different cements.

A discussion took place regarding the merits of various machines for the preparation of the briquettes. Two machines of different construction have hitherto been used; Dr. Böhme's, on the principle of a tilt-hammer, and Kæmp's, which resembles a pile-driver in its action. It was remarked that Kæmp's machine gave irregular results according to the lubrication of the guide-rod. Böhme's apparatus was adopted as the one to be used for standard tests.

A report was read upon the results of the conference at Munich, the object of which was to decide upon uniform methods of testing building-materials. At this conference a number of resolutions were passed with reference to the testing of cement, limes, and other materials.

A long discussion ensued upon the revision of the standard rules for testing cement. Several important alterations were made, and in their amended form these rules were adopted.

The question of adulterated cement played an important part in the proceedings, and it was stated that the export trade in German cement to Australia, which had become considerable, had been seriously injured through the shipment to that country of a large quantity of cement of very inferior quality.

Dr. Böhme gave the results of some experiments made to ascertain the resistance to abrasion offered by twenty-eight different kinds of cement. The samples were pressed upon a cast-iron disk rotating at the rate of twenty-two revolutions a minute, a weighed quantity of emery being supplied at fixed intervals.

Of seventy-nine cements tested according to the standard rules at the Berlin testing station in 1883–4, sixty-seven had a tensile strength of more than 213 lbs. per square inch (15 kilograms per square centimetre), forty were above 284 lbs. per square inch (20 kilograms per square centimetre), and one above 427 lbs. per square inch (30 kilograms per square centimetre).

W. F. R.

Failures in various Works, owing to the employment of Magnesian Cements. By L. Durand-Claye and — Debray.

(Annales des Ponts et Chaussées, 6th series, vol. xi., 1885, p. 845, 1 plate.)

The employment of a kind of Portland cement made in some new works at Campbon (Loire-Inférieure) was authorized in 1876 for construction in fresh water, or out of water, in consequence of some tests made with it at the Port of St. Nazaire, and in the

laboratory of the École des Ponts et Chaussées. This Campbon cement was accordingly used in the arches of three railway bridges over the River Oust, opened in 1881, and in the abutments of a railway bridge at Nantes, built in 1882–83. Fissures, however, appeared in these works about a year after their completion, which could be clearly traced to the swelling of the cement in the joints under the influence of moisture. In a roadway bridge, half of the small brick arches between the two girders were laid in Boulogne cement, and half in Campbon cement; and whilst in the former half the arches remained intact, in the latter half the arches were dislocated, rose, and disturbed the footpath. The overthrow also of boundary walls, pointed on one face with Campbon cement, and disruptions of masonry laid with this cement in various buildings, have resulted from the swelling of the cement. Analysis showed that Campbon cement contains a large proportion of magnesia, amounting in five samples to between 16 and 28 per cent.; and the swelling of the cement was naturally attributed to this cause. This was confirmed by the action of sound cements mixed with calcined magnesia, which swelled under water in proportion to the quantity of magnesia in the mixture. The large quantity of magnesia contained in the rocks from which this cement is manufactured does not wholly combine with the silica in the rocks; and this magnesia, having been calcined during the burning, is gradually hydrated, and swells. The hydration depends upon the degree and the duration of the burning. The cement might last if mixed with little water, and in a perfectly dry locality; but when mixed with plenty of water, and in a moist atmosphere, it swells rapidly, and is certain to dislocate any work in which it is used.

L. V. H.

On the Change of the Elastic Limit and Strength of Iron and Steel, by Drawing Out, by Heating and Cooling, and by repetition of Loading.

By J. Bauschinger.

(Mittheilungen aus dem Mechanischen Technischen Laboratorium der k. Hochschule in München, 1886, p. 1–115.)

Of this extremely elaborate Paper containing a mass of experimental researches, only a summary of the principal conclusions can be given. Starting from the fact that loading a bar beyond the elastic limit raises the elastic limit for a subsequent load, a fact observed first by Uchatius and himself, the Author proceeds to investigate this phenomenon more closely. His conclusions are the following:—

(1.) By drawing out a bar of Bessemer steel, that is, by loading it beyond its breaking-down point, its elastic limit rises, not only during the time the load acts, but during a rest after unloading.

This action asserts itself even beyond the load with which the bar was stretched.

(2.) The breaking-down point is immediately raised to the load with which a bar is drawn out. Resting after unloading, the breaking-down point rises above the maximum load previously applied. This increase, still sensible after some days, lasts perhaps for months.

(3.) The elastic limit is, by drawing out, lowered, often to zero; so that if immediately after drawing out and unloading, the measurements are again taken, either there is no elastic limit, or a lowered one. But resting after the drawing out and unloading, the elastic limit rises again, and reaches, after some days, the load with which the bar was drawn out, and will, after a sufficiently long time, be raised above this limit.

(4.) Similarly to the elastic limit, the modulus of elasticity is lowered by drawing out. But it rises during a rest afterwards. After some years it is higher than its original value.

(5.) By extension with loads above the elastic limit, but below the breaking-down point, the elastic limit is raised. If the load approaches the breaking-down point, the elastic limit reaches a maximum, and by overstepping the breaking-down point it is lowered.

(6.) Powerful vibrations, in cold conditions of the bar, lower the elastic limit raised by drawing out, and a subsequent period of rest. The breaking-down point is also lowered but not much.

(7.) For ingot-iron, heating and cooling at 350° C. if the cooling is rapid, and at 450° C. if the cooling is slower, sensibly influence the elastic limit and breaking-down point. For weld-iron, this action occurs at 400° C. whether the cooling is rapid or slow.

(8.) The action of heating above those temperatures, and quick or slow cooling afterwards, always lowers the elastic limit and breaking-down points.

(9.) By loads in tension or compression above the elastic limit, the elastic limit in compression or tension respectively is lowered, and so much more, the more the elastic limit is exceeded. For a comparatively small excess over the elastic limit by a stress of one kind, the elastic limit for the opposite stress is lowered to zero. If a so-lowered elastic limit is raised by stress of a similar kind and then exceeded, the elastic limit for opposite stresses is in turn lowered to zero, or almost to zero. Time in these cases has little influence.

(10.) By gradually increasing stresses varying from tension to compression, the elastic limits for opposite stresses are first lowered, when those stresses exceed the original elastic limit.

(11.) If the elastic limit for tension or compression is lowered by loads in compression or tension, which exceed the original elastic limit, it can be raised by gradually applied loads changing from tension to compression, but only to a limit below the original elastic limit.

(12.) If a bar is strained by repeated tensions, the lower

limit of which is zero, and the upper limit is near the original elastic limit, several million changes of load will not cause fracture.

(13.) By often repeated loadings between zero and an upper limit of stress, which is near or above the original elastic limit, this is raised so much the more the greater the number of repetitions, but without passing a certain limit.

(14.) Repeated strainings between zero and an upper limit, which raise the elastic limit up to the upper limit of stress, do not cause fracture. But if the upper limit of stress is above that to which the elastic limit can be raised, a limited number of repetitions must cause fracture.

(15.) The limits of stress, when a bar is subjected to alternate equal tension and compression, ought not to exceed the natural elastic limit.

W. C. U.

Specifications for the Strength of Iron Bridges.

By J. M. Wilson, M. Am. Soc. C.E., M. Inst. C.E.

(Transactions of the American Society of Civil Engineers, 1886, p. 389.)

The Author describes the terms of a general specification which he has now adopted as a standard for all bridges on the Pennsylvania railroad, and whose provisions may be classified under the following heads:—

1st. The external forces to be provided for—including prescribed values of the rolling-load, wind-pressure, and centrifugal force (on curved viaducts).

2nd. The basis on which the stresses resulting from these forces should be calculated.

3rd. The allowed working unit-stress—this is not a constant, but is to be computed by a certain modification of the Launhardt-Weyrauch method, and to be further reduced in long struts by applying a formula akin to that of Professor Rankine.

4th. The required quality of the material, as tested for tensile strength, elastic limit, ultimate extension, and behaviour under cold bending; and the required quality of workmanship as indicated by general stipulations.

5th. Certain prescribed details of construction connected with the bridge-floor, cross-ties, wheel-guards, &c.; and some rules for the dimensions of secondary bracing, plate-webs, stiffeners, riveting, &c.

In view of the increasing requirements of the traffic, the stresses due to rolling-load are taken at the maximum value resulting from three supposed cases; each track is supposed to be traversed by a train of cars weighing 3000 lbs. per foot lineal, the trains moving

simultaneously in the same direction, and each train being headed by an engine or engines of the following weights:—

	Weight of each Engine and Tender.	Wheel-base of Engine.	Greatest Load on Drivers.
	Tons.	Feet Ins.	lbs.
a. Two 10-wheeled engines . . .	86	21 0	24,000
b. Two 8 " " . . .	88	22 6	40,000
c. One 6 " " . . .	66½	10 8	34,000

The distribution of the weights on the wheel-base of engine and tender is given for each case by a diagram. "In calculating the web-members of trusses, the load under the drivers is to be considered as the head of the train," neglecting the compensating effect of the load on the leading wheels. The way in which the dead-load is to be divided between the upper and lower joints of the truss is also prescribed. The maximum and minimum stresses in compression and tension, as found for the above loads, are to be used in determining the permissible working stress *a* in each piece of the structure, according to the following formulas:—

For pieces subject to one kind of stress only, alternating from min B to max B,

$$a = u\left(1 + \frac{\text{Min B}}{\text{Max B}}\right) \quad . \quad . \quad . \quad . \quad (1)$$

For pieces subject to stresses in opposite directions, whose greatest values are max B_1 and max B respectively,

$$a = u\left(1 - \frac{\text{Max B}_1}{2\text{ Max B}}\right) \quad . \quad . \quad . \quad (2)$$

in which B_1 is the lesser of the two opposite stresses, while *u* is to be taken at the following fixed values:—

In Tension.	lbs. per sq. inch.
"Double-rolled iron" (links or rods)	$u = 7{,}500$
"Rolled" iron (plates or shapes)	$u = 7{,}000$
Rolled iron in compression	$u = 6{,}500$

The value of *a*, thus found for compressive stress, is to be inserted in the formula $b = \dfrac{a}{1 + C\dfrac{l^2}{r^2}}$, in order to determine the working stress *b* per unit of sectional area in compression members. In this formula *l* is the length and *r* the least radius of gyration, while C is to be taken at the following values:—

For struts with both ends fixed . . . $C = \frac{1}{36{,}000}$

" with one end hinged . . . $C = \frac{1}{24{,}000}$

" with both ends hinged. . . $C = \frac{1}{18{,}000}$

In the compression flanges of girders, the working stress is to be $b = \frac{a}{1 + \frac{l^2}{5{,}000\, w^2}}$, in which l is the unsupported length, and w is the width of flange; and in no case is the stress to be greater than for a length equal to twelve times the width of flange. Rules are also prescribed for the shearing-stress on rivet-sections, the bearing area of pin-connections, and for the bending stresses which may arise when the joints do not coincide with the neutral axis of all the connected members, or when the load between the joints is carried directly upon the upper flange of deck-bridges.

In selecting the above forms of expression for the working stress, the Author quotes the formulas of Launhardt and Weyrauch, viz., for pieces subject to one kind of stress only,

$$a = u\left(1 + \frac{t - u}{u} \cdot \frac{\text{Min B}}{\text{Max B}}\right),$$

and for opposite stresses

$$a = u\left(1 - \frac{u - s}{u} \cdot \frac{\text{Max B}_1}{\text{Max B}}\right),$$

in which the ultimate unit strength is expressed by

a = ultimate strength under working conditions,
t = „ „ for a single static load,
u = „ „ for any number of repetitions of load,
s = „ „ for repetitions of equal and opposite stresses.

Assuming with Weyrauch that $t = 1\frac{1}{2}\, w$, and $s = \frac{1}{2}\, w$, it would follow that

$$a = u\left(1 + \frac{\text{Min B}}{2 \text{ Max B}}\right),$$

and

$$a = u\left(1 - \frac{\text{Max B}_1}{2 \text{ Max B}}\right).$$

But the Author considers that these formulas do not take account of the question of impact, a question which has been treated by many engineers by merely adding a percentage to the stresses due to rolling load. The Author reviews these percentages as adopted in the practice of Mr. B. Baker, the Edge Moor Iron Company, the Keystone Bridge Company, and Messrs. Bouscaren, Moulton, and Shaler Smith; but he concludes that a more rational method is that of Professor Cain, who assumes that "as impact is due to and increases with the action of the live load on a member, its effect will vary inversely with $\frac{\text{Min B}}{\text{Max B}}$," and accordingly he writes

empirically $a = \frac{u}{n}\left(1 + \frac{\text{Min B}}{\text{Max B}}\right)$, n being a factor of safety. This is equivalent to making the value of $t = 2u$ instead of $1\frac{1}{2}u$ in Launhardt's formula. Adopting this relationship, but still retaining the value $s = \frac{1}{2}u$, the formulas are written in the form above given in (1) and (2). The resulting working stresses for different values of $\frac{\text{Min B}}{\text{Max B}}$, and $\frac{\text{Max B}_1}{\text{Max B}}$, are represented in a diagram which consists of straight lines, and the following values occur in the extreme cases:—

	Working Stress in lbs. per square inch. Tension. Bars.	Plates.	Compression.
Load constant, Min B = Max B .	15,000	14,000	13,000
Varying from 0 to Max B . . .	7,500	7,000	6,500
Varying from − Max B to + Max B	3,750	3,500	3,250

The Paper also quotes experimental reasons for fixing the coefficient C (in the formula for long struts) at the values above given.

In regard to wind-pressure, it is specified that the lateral bracing shall be proportioned for a pressure of 30 lbs. per square foot on the whole surface of the truss as seen in elevation, in addition to a train of 10 feet average height, beginning 2 feet 6 inches above base of rail; and in addition for the centrifugal force which may arise on curves, from the passage of a train on each track running at 60 feet per second. But in the case of these members, the working stress is fixed at 15,000 lbs., and 12,000 lbs. for tension in rods and plates respectively, and at 12,000 lbs. per square inch for the compressive stress a in the formula for struts; and in the case of main chords the maximum stresses due to the combined effect of load, and of wind-pressure and centrifugal force, shall not exceed the same limits of working stress. Trestles and iron piers are to be proportioned for the vertical load with the same working stresses as those given for trusses, and under the combined stresses due to load, wind and centrifugal force, the stresses are not to exceed the values fixed for the lateral bracing.

In addition to the above, the structure shall be capable of resisting wind-pressure on its exposed surface alone of 50 lbs. per square foot, without exceeding the limiting stresses fixed for wind-bracing.

Numerous rules are given for the construction and stiffening of plate-webs, the spacing of rivets, and the proportions of eye-bars; and the Author alludes incidentally to a new method of manufacture adopted by the Edge Moor Company, by which the full theoretic strength of eye-bars, in both iron and mild steel, is secured with moderate proportions of the swelled head.

T. C. F.

Automatic Apparatus for controlling Stresses in Iron Bridges.

(Wochenschrift des österreichischen Ingenieur- und Architekten Vereines, 1886, p. 324.)

In view of the present want of experience as to the normal life of iron bridges under the most careful conditions of maintenance and inspection, and the contingency that at some date internal disintegration or other causes may induce catastrophes under moving loads, the Author has endeavoured to set out an ideally safe girder, which somewhat resembles in outline the Schwedler bridge, the parabolic curve being depressed in the two central bays in adaptation to the lines of stress. The girder rests on double bearings or beds at each end. The weight is transmitted direct on to a roller-balance frame projecting beyond the face of the abutment, the outer end carrying a counterbalance weight. From this frame part of the stress is transmitted through upright and diagonally-arranged levers to an upper or secondary bed-plate, to which the lower flange is extended by horizontal tie.

Denoting W = pressure on lower (balance) bed-plate;
S = transmitted pressure through levers to upper bed-plate;
G = counterbalance weight,

and the leverages respectively r, r_1, and r_2; the equalization of the three forces is expressed by the equation—

$$W_r + S_{r_1} = G\,r_2.$$

Taking dead load on one girder per unit length $= p$, live load $= k$, total load $p + k = q$, there follows from the above—

$$\text{For dead load: } \frac{pL}{2}\,r + S\,p\,.\,r_1 = G\,r_2;$$

$$\text{For total load: } \frac{qL}{2}\,r + S\,q\,.\,r_1 = G\,r_2;$$

or, if pressure on the secondary bed-plate is eliminated—

$$G = \frac{qL}{2} \cdot \frac{r}{r_2}.$$

Employing this value of G in the equation for dead-load, the stress in the vertical arm, in the normal state of the bridge becomes:—

$$S\,p = \frac{kL}{2} \cdot \frac{r}{r_1},$$

and the moment of stress thus transmitted—

$$M = \frac{kL}{2} \cdot \frac{r}{r_1} \cdot \frac{h}{\tan\alpha}$$

h being height of vertical arm above under side of girder, and a the angle between the diagonal member and the horizontal.

These values are fixed for practical construction, so that with full live-load the stress is taken off the diagonals, and the flanges are equally strained throughout. Calling the coefficient $\frac{r}{r_1} \cdot \frac{h}{\tan a} = t$, with the stress from a load P at a distance x from point of support A, the reactions at each end are (R at A, and R_1 at B):—

$$R = \frac{L - t - x}{L - 2t} P + \frac{pL}{2}$$

$$R_1 = \frac{x - t}{L - 2t} P + \frac{pL}{2},$$

and the resulting moments of stress respectively—

$$M = \left\{\frac{kL}{2} - \frac{L - t - x}{L - 2t} P\right\} t,$$

and $$M_1 = \left\{\frac{kL}{2} - \frac{x - t}{L - 2t} P\right\} t.$$

The minimum values for any point being—

$$M = \frac{L - t - x}{L - 2t} Pt,$$

and $$M_1 = \frac{x - t}{L - 2t} Pt.$$

Taking now the coefficient as greater than the greatest distance of point of section on flange from the point of support A, P is lessened so that the stresses from the counterbalance weight and the dead load are minimized in all parts. With the stress under full load, the working moment at both ends = 0.

If the parabolic form is continued in the upper flange, through the two central bays, with a girder of 8 bays $t > 2 \cdot 5$ L, and moment $M > \frac{5kL^2}{4}$. By altering these central bays, $t > 1 \cdot 25$ L and $M > \frac{5kL^2}{8}$, and the stresses in the unloaded and loaded flanges are about as 3 to 1. Though more material is required in this form of construction, yet as any breakdown must occur at the moment of increased stresses, it is evident that by this disposal of stresses this increase occurs when the live-load is removed.

P. W. B.

Railway Bridge over the Warnow at Rostock.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 1001.)

The new line from Neustrelitz to Warnemünde, shortening the route between Berlin and the Baltic coast, crosses the Warnow a short distance from Rostock, at a point where the river, which is an important navigable channel, is about 200 feet in width. The embankment, which is 41 feet high, is on very soft soil, overlying the more solid stratum to a thickness of from 30 to 40 feet.

The original design was for one clear span with two abutments; but in view of the heavy work thus required, and in carrying the foundations to so great a depth, two piers were built on the river banks, and the girder forms a central opening and two cantilevers, the slope of the embankment being rounded off clear of each pier. The three spans are 47 feet $5\frac{1}{4}$ inches, 221 feet $4\frac{1}{2}$ inches, and 47 feet $5\frac{1}{4}$ inches: the whole girder being thus 316 feet 3 inches in length, with a depth of 31 feet $7\frac{1}{2}$ inches = $\frac{1}{10}$ length, and divided into twenty bays of 15 feet $9\frac{3}{4}$ inches, fourteen of which are in the central span and three in each cantilever. A strong vertical member is placed over each pier. The structure is provided throughout with upper and lower horizontal diagonal wind-bracing, calculated for a pressure of 51·25 lbs. per square foot (on each girder) and 30·75 lbs. per square foot on moving load. The rails are carried on transverse sleepers resting on longitudinal bearers, and a single line only is at present laid; but the piers are constructed to the full width for double line, so that the superstructure can be completed at any time. The weight of iron in the structure is 218 tons; and the amount saved by the method of construction adopted, as compared with the original project with the ordinary abutments, is £4,000.

The chief peculiarity of the bridge is the arrangement by which the ends of the cantilever rest on the embankment at each extremity of the structure. The last cross-girder on the cantilever serves as a point of support to a framing equal in length to one bay (15 feet $19\frac{3}{4}$ inches), and consisting of 2 side-girders, 3 cross-girders, and diagonal bracing. For free lateral motion this framing is hinged on a vertical pivot fixed between the flanges of the last cross-girder; while vertical motion is secured by the pivot working in oblong slotted guides in the transverse member of the framing. At the other end, where the permanent way passes from the bridge-platform to the embankment, the bed-plate at each side rests on a roller bed, but instead of being a fixed part of the framing, is an independent plate attached to a screw-jack, by which the end of the framing can be raised or lowered. The roller-beds are fixed on a box-girder surrounded by back and side casing to prevent any earth from slipping on to the bed-plates. By this arrangement of lateral and vertical play and end-level adjustment, the continuity of permanent way is secured under all varying conditions: whether

the cantilever alone is loaded and depressed, or the central span loaded and depressed and the cantilever raised, or the bank sinks to any slight extent, or any side deflection is caused by pressure of wind upon the structure.

P. W. B.

Recently constructed Bridges in Switzerland. By O. Riese.

(Zeitschrift für Bauwesen, 1886, pp. 213 and 351.)

The general progress of railway and road construction in Switzerland, and also the most important of the earlier bridges, are reviewed by the Author, and detailed descriptions, illustrated by numerous diagrams and drawings, are given of many of the larger railway and road bridges constructed about the year 1870, or since. Amongst railway bridges the following are described, viz.:—

1. *The Aare Bridge at Brugg.*—This was erected in 1874–75, and carries the Nord-Ost railway at a height of 98 feet 6 inches above the River Aare; it is in five spans, the central opening being 191 feet 3 inches, and those adjacent on either side 156 feet 6 inches each; the end spans are each 121 feet 9 inches. The railway is here on a curve of 1,575 feet, and on a gradient of 1 in 83·3. The girders are formed with convex upper and lower flanges (double-bow), trussed with vertical and counter-diagonal web bracing, forming bays of 17 feet 5 inches each; the depths at their centres vary from 28 feet 6 inches to 17 feet 9 inches, according to the span. They are 13 feet 1½ inches apart, centre to centre, and those on the outside of the curve are made slightly stronger than those inside, to resist the centrifugal force of the trains. The rail-level is above the main girders, and the platform is formed by outside longitudinal plate-girders, supported by prolongations of the verticals of the main girder web-bracing. The piers and abutments are of masonry, and are constructed for a double line, although at present the girders are erected for a single line only. The centre piers are 88 feet 7 inches high, and 11 feet 9½ inches broad at the top, with a batter of 1 in 15. At a little less than half their height they are pierced for a footway, carried by a suspension bridge.

The weight of iron in the construction was 431·4 tons, or 0·56 tons per lineal foot, and cost £15,720. The total cost of the bridge, exclusive of the suspension footway, was £32,760, or 10*s.* 1*d.* per square foot.

The footbridge extends across the three centre openings, and is 508 feet 5 inches long; it is supported by two wire cables, each with a net section of 3 square inches. The piers being built radially to the curve, one cable is 2½ per cent. longer than the other. On testing the centre span with a load of 11·8 tons of rails, the cables were stretched to an unequal extent, resulting

in a permanent tilt to the platform of 3⅝ inches. The cost of footbridge was £1,520, or £2 19*s.* 3*d.* per lineal foot.

2. *Guggenloch Viaduct at Lütisburg on the Toggenburg Valley Railway.*—This was the first bridge erected in Switzerland with wrought-iron piers. A Table is given of the dimensions and weights of four earlier constructed bridges (1854–57), viz., the Zitter, Thur, Glatt, and Saane, the piers of which were mainly of cast-iron. The height of their piers varies from 48 feet 2 inches to 155 feet 10 inches, and the weight of iron per foot of their height from 1·51 ton to 2·68 tons.

The Guggenloch viaduct was erected in 1869–70, and crosses the valley at a height of 177 feet 2 inches, by three spans, of which the centre is 188 feet 1 inch, and the end each 155 feet.

It is constructed for a single line of railway, with continuous parallel flanged lattice main-girders 16 feet 3 inches deep, and 11 feet 4 inches apart, centre to centre, provided with expansion-rollers at the abutments only. The cross-girders rest on the top flange of the main girders. The wrought-iron piers are 99 feet 5 inches high, from the masonry pediment to the underside of the girders; they are formed by four columns braced together horizontally and counter-diagonally in bays of 9 feet 4 inches of height, with channel iron. Each column measures internally 11¾ inches square, and is made up of four channel-irons rolled to a special section, viz., with flanges of 45° instead of 90°; the latter are ¾-inch and ⅜-inch thick in the lower and upper part of the column respectively, and are connected and stiffened at the corners by tee-irons. They are not riveted, but bolted together. At their base the piers, which batter 1 in 15, measure 24 feet 3 inches by 12 feet 2 inches, from centre to centre of columns. The weight of wrought-iron in the piers is 153·5 tons, or 0·75 ton per foot of height, and in the superstructure 265·75 tons. The cost of the ironwork was £14 2*s.* 1*d.* per ton, of the masonry, £703 10*s.* 6*d.*, £776 16*s.* for the left and right abutments, and £2,005 12*s.* and £1,327 4*s.* for the left and right pier-bases.

3. *Thur Bridge at Ossingen.*—This was constructed in 1873–75, and carries the National Railway across the valley at a height of 147 feet 8 inches; there are five spans, of which the three middle are each 236 feet 3 inches, and the end ones 187 feet, span. The structure is for a single line, with parallel flanged lattice main-girders, 23 feet deep and 14 feet 5 inches apart centre to centre. For calculation, the weights assumed were, for the girders, permanent-way, &c., 0·675 ton per foot, and a rolling-load of 1·2 ton per foot, the working stress per square inch being limited to 5·08 tons. The cross-girders are riveted to the vertical stiffening-plates of the top flange.

The four piers are of wrought-iron, resting on masonry pediments, and each made up of four raking columns, the latter of circular section, 78 feet 9 inches in height, and battering 1 in 32 and 1 in 24 in the direction of the longitudinal and transverse axes of the viaduct respectively. Each column is composed of thirteen

cylinders, of about 6 feet 7 inches in length, and 1 foot 9½ inches diameter; they are made of boiler-plate, from ½-inch to ⅝-inch thick, with riveted butt-joints and cover-plates, and angle-iron flanges at their ends; the lengths of cylinders are bolted together. Expansion-rollers are provided for all the bearings but one. The weight of the wrought-iron piers was 177·12 tons, or 5·5 tons per foot of height, and of the superstructure 688·8 tons, or 0·64 ton per lineal foot.

	£
The cost of the ironwork in the superstructure (*Eisenverbindung*) was	24,400
The cost of the abutments, piers, foundations, &c. (*Unterbau*)	22,000
Total	£46,400

4. *The Bridge over the Rhine at Stein* is for a single line, and carries the Ertzweilen Singen Railway at a height of 96 feet 9 inches above the bed of the river. There are four spans, of which the two centre ones are 229 feet 8 inches each, and the side ones 187 feet 4 inches each. The main-girders comprise a single system of counter diagonal and vertical web-bracing, in bays of 20 feet 10 inches, and are 21 feet 4 inches deep. The cross-girders are riveted to the stiffening-plate of the top flange of the main girders, which latter are fixed at the centre pier, and free to move on steel rockers at the other points of support.

The piers are of wrought-iron framing, made up of four raking standards, battering 1 in 14 and 1 in 6·8, longitudinally and transversely to the line of the viaduct respectively, braced together with tee-iron and based on masonry pediments; they measure 14 feet 9 inches by 5 feet 8 inches above, and 29 feet 6 inches by 13 feet 2 inches at the base. The cross-section of the standards (or columns) is different from those of the other bridges; they are L-shaped, and made up of two channel-irons 11¼ inches by 3⅜ inches by ⅝-inch, backed by plates of 9½ inches by ⅜-inch, and stiffened at the extremities by angle- and bulb-irons.

	Tons.
For the main girders the working stress per square inch is limited to	5·08
For the cross girders and longitudinal rail-bearers per square inch is limited to	3·80

	£
The cost was as follows:—Ironwork, including carriage	14,316
„ „ Masonry, &c.	21,200
	£35,516

To save masonry, the wings of the abutments, for part of their length, are not carried down to the foundation level, which is deep, but are supported on girders, 15¾ inches deep and 19 feet 8 inches long, built into the masonry of the abutment, and projecting about 8 feet 3 inches.

5. *The Bridge over the Reuss at Mellingen.*—This was constructed in 1877, and carries a single line of railway at a height of 151 feet above the river. There are three openings of 164 feet, 196 feet 10 inches, and 164 feet span, over which the girders are continuous, and a fourth opening of 98 feet 5 inches span, with independent girders. The piers on each side of the centre span are of wrought-iron framing, based on masonry pediments; but the third pier and the abutments, are of masonry.

The main-girders are formed with a single system of counter-diagonals, without verticals, in 16-feet 5-inch bays, their depth over the main spans being 16 feet 5 inches. The cross-girders are riveted to the vertical stiffening-plate of the top flange. The wrought-iron piers are of the same type as those of the Thur bridge at Ossingen. Each pier from the masonry pediment to the girder bed-plate is 107 feet 3 inches high, and formed by four cylindrical columns of 2 feet outer diameter, braced together with channel-iron. The wrought-iron piers measure 14 feet 9 inches by 7 feet 4½ inches above, and 31 feet 2 inches by 15 feet 7 inches below.

A Table is given comparing this and the three preceding bridges as regards dimensions and weights of wrought-iron piers per metre of height and of area. For the Guggenloch and Thur bridges the weight per foot of height of pier is 0·75 and 0·55 ton respectively, the height of the wrought-iron part of the pier being 99 feet 5 inches and 80 feet 5 inches respectively.

In the four bridges the weight of wrought-iron per square foot of area of surface of outline of pier varies from 5·75 to 6·31 lbs.

The Author then alludes to five recently-constructed road-bridges, two of which, viz., that over the Schwarzwasser, at Berne, and that over the Rhine at Basle, are fully described and illustrated. They are, all but one, arched bridges.

The Javroz Bridge, near Freiburg, was constructed in 1878–80, in place of a timber structure, and carries the road from Bulle to Charney across the valley, at a height of 183 feet 9 inches, by a wrought-iron parabolic arch of 281 feet 4 inches span and 64 feet 8 inches rise. The depth of the arch at crown and springing respectively is 4 feet 11 inches and 8 feet 10 inches, and the breadth of roadway 15 feet 9 inches. The weight of ironwork was 201·7 tons, and its cost £3,700, and the total cost of the structure £7,800.

The Schwarzwasser Bridge at Berne.—This was constructed in 1881–82, and carries the road from Berne to the district of Schwarzenburg by a wrought-iron flying parabolic arch of 374 feet 1 inch span, and 70 feet 6 inches rise, at a height of 197 feet above the bottom of the valley. There are two framed main ribs, 4 feet 11 inches and 11 feet 6 inches deep at the crown and springing respectively, the face of the arch and spandrels battering about 1 in 20, whereby the distance apart of the ribs, which is 19 feet 8 inches at the crown, is increased to 26 feet 3 inches at the springing. The weights assumed for the calculations were a total of 166 lbs. per square foot, and the cross-girders and longitudinals

calculated for a moving load of 9·84 tons and 9·84 feet wheel-base.

The working stress is limited to 4·45 tons per square inch for the spandril columns, and 5·08 tons elsewhere.

The weight of iron is 423·1 tons, and the cost of the structure was £11,180, which included £1,760 for the timber scaffolding and centering. The cost per square foot of area (in plan) was £1 0*s.* 10*d.*

The Kirchenfeld Bridge at Berne was constructed in 1882–83. It is in two spans, each of 264 feet 9 inches and 74 feet 2 inches rise, carrying the road at a height of 114 feet 10 inches above the valley; the depth of each arch at the crown and springing is 4 feet 11 inches and 9 feet 6 inches respectively; the breadth of the roadway is 43 feet 4 inches, the weight of ironwork 1,322·5 tons, the cost of the iron £28,340, and the total cost of the structure £43,100. The cost per square foot of area (in plan) was £1 6*s.* 5*d.*

The Upper Rhine Bridge at Basle.—This bridge connects Great and Little Basle, and owing to the difference in level between the two banks of the river, is constructed on the incline. It is in three spans of 211 feet 3 inches, 201 feet 5 inches, and 191 feet 7 inches, counting from the left bank. In the same direction, the road falls at the rate of 1 in 32·3 over the first or main-stream span, and thence over the other two arches at 1 in 37·5; on the right bank the approach, flanked by wing-walls, is horizontal, and pierced by four small arches. Each arch is composed of five wrought-iron ribs, 9 feet 6 inches apart, which are 2 feet 7½ inches and 3 feet 5¼ inches deep at the crown and springing respectively, and are each formed of two parallel plate girders, 1 foot apart, braced together. The longitudinal horizontal girders are of the same form of section as the arched ribs, and are 11 inches deep. The floor is formed by troughing-plates.

The piers are of limestone and granite, the height being 36 feet 1 inch from the river bed to the springing of the arch, and 16 feet 1 inch and 22 feet broad at the springing and base respectively. In the breadth of the bridge there are two footways, each 8 feet 2½ inches broad, and a roadway of 25 feet. In those portions of the structure where the stresses alternate from compression to tension, the working stress does not exceed 3·8 tons per square inch; but where strained in one manner only, 4·8 tons, and the total cost £82,400.

	Tons.
The total weight of wrought-iron was	941·7
And of cast-iron, including balustrade	244·0
Total	1,185·7

D. G.

Long-Span Bridges and their Construction in Steel.

By A. BARBET, Engineer-in-Chief of the Société Cail.

(Annales des Ponts et Chaussées, July 1886, p. 97.)

To illustrate the economy which is attainable by the employment of steel in the construction of long-span bridges, the Author calculates in detail the weight of steel required for double-line railway bridges, designed upon a particular model, and varying in span from 100 metres to 400 metres, or from 328 feet to 1,312 feet, English.

The working stress in the principal members is taken at 12 kilograms per square millimetre = 7·62 tons per square inch; but for cross-girders and longitudinal bearers the stress is reduced to 10 kilograms. The adoption of these values is justified by reference to the principles which have guided the French government in fixing the working stress for wrought iron at 6 kilograms per square millimetre; and by reference to the opinions of General Poncelet, who considered it judicious to limit the working load to about one-half of the elastic limit. Thus, taking the elastic limit in good steel at 24 kilograms per square millimetre, the Author fixes the maximum working stress at one-half that amount, and by way of comparison he refers to the Niagara, Bismarck, and Plattsmouth bridges recently erected in America, in which the working stress is 10·8 kilograms—a limit which has been raised to 11·8 kilograms in the bridge across the Forth.

The form of construction selected to illustrate the capabilities of steel is that of the braced arch, the proportions of the structure being the same for all spans from 100 to 400 metres. The designed bridge consists in every case of a pair of arched ribs, inclined inwards from the base, and united by transverse bracing. The railway is carried at the level of the crown, the longitudinal girders being supported by vertical spandril-columns. The arched ribs are hinged at the springing, and have a uniform depth throughout, the two flanges, or parallel arcs, being united by bracing in the vertical plane.

Taking the span as unity, the rise of the arch is in all cases equal to 0·10, while the depth of rib, measured between the centres of gravity of the flanges, is 0·0275; and the distance between the spandril-columns is fixed at 0·025, or $\frac{1}{40}$ of the span.

With these fixed dimensions, the stresses are found by graphic methods which relate to three problems:—1st, to determine the thrust of the arch due to weights placed in any position; 2nd, the stresses existing in different sections of the arch; 3rd, to find the situation of the rolling load which produces, in any given section, the greatest stress.

The diagrams having been constructed, the required sectional area of the principal members is given in a Table, along with the total stress for which they are calculated—the latter being made

up of three items, viz., the stresses due respectively to dead load, live load, and change of temperature.[1] The effect of speed is regarded as being insufficient to appreciably influence the stresses in a long-span bridge. The centrifugal force due to the passage of the train over the deflected bridge is assumed to have been annulled by adopting a corresponding initial camber, and it remains only to consider the dynamic effect of the rapidly applied load. This effect is also regarded as inconsiderable: thus, in a bridge of 400 metres, the rolling load forms less than one-fourth of the total weight, and even if it were applied instantaneously, it could not do more than to double the corresponding element of the stress; *i.e.*, it could only increase the total stress by one-fourth. But the effect would be far less in reality, because even at a speed of 30 miles an hour, it would take twenty-eight seconds to cover the length of the bridge; and, according to a formula of Mr. Reval, the Author calculates that the dynamic increase of stress due to this cause would only amount to 3 per cent.

By the methods above mentioned, the Author calculates the total weight of the arched bridges as follows, including flooring and permanent way:—

Span.	Total dead weight per foot lin.
100 metres = 328 feet	1·32 tons (English).
150 „ = 492 „	1·68 „
200 „ = 656 „	2·25 „
300 „ = 984 „	3·30 „
400 „ = 1312 „	4·56 „

The total dead weight of the Forth bridge is given as 6·60 tons per foot of span. The Paper contains a list of the actual weights of forty-six bridges, built, or in course of construction, and having spans of 300 feet and upwards; and the following comparison is made in regard to the relative economy of iron and steel:—

A span of 100 metres in steel, has the same weight as one of 50 metres in iron.
„ 150 „ „ „ 75 „
„ 200 „ „ „ 100 „
„ 300 „ „ „ 130 „
„ 400 „ „ „ 160 „

In conclusion the Author remarks that foreigners do not hesitate to undertake great works. In France engineers have preferred to modify or extend the line of route, so as to avoid such works, or to reduce the span by increasing the number of supports. But the Author has endeavoured to show the advantage of employing steel, and accepting the construction of long-span bridges. As a case in point, the line from Marseilles to Neussargues is quoted, for in this instance by constructing across the Garabit valley a viaduct including an arch of 540 feet, the line was greatly improved, and its cost reduced by upwards of three millions of francs.

T. C. F.

[1] In the list of stresses the effect of wind-pressure does not appear to be included.

Fall of a Suspension Bridge over the Ostrawitza at Mährisch-Ostrau.

(Wochenschrift des österreichischen Ingenieur- und Architekten-Vereines, 1886, p. 308.)

On September 15th, 1886, as a squadron of Uhlans was crossing this bridge, the structure gave way so suddenly that the whole troop was precipitated into the river amongst the ruins; six men being killed on the spot and a large proportion of the remainder severely injured.

The bridge was commenced in 1846, but, its construction being delayed by floods, it was not completed till June 1851. It was erected under the supervision of the technical department of the provincial government of Teschen. Though only a little over thirty-five years in use, it had for some time been thought unsafe, but no immediate danger was anticipated; and it is probable that it was not the actual load but the swinging action of the squadron of cavalry which actually caused the disaster.

The fracture occurred in one of the anchor-chains, in an open chamber in the masonry, within arm's length of the exterior. The material was thoroughly altered in character, the iron being oxidised through, so that it could be crushed in the hand. The anchor-stays in question consisted of twelve links, of which one was completely rusted through: the others were reduced to about one-sixth of the original section.

The total length of the bridge was 310 feet 10 inches, and of the central span 216 feet 6 inches, width 23 feet 3 inches, and towers 16 feet high. At the moment of the accident there were on the bridge thirty persons, sixteen horses, one loaded coal wagon, and an empty cart—altogether about $12\frac{3}{4}$ tons. The bridge has often, even lately, carried three hundred people at a time. As far as can be ascertained the weight of the chains (including bolts and eyes) was about 181 lbs. per lineal foot, and of road platform 1005 lbs., together = 1186 lbs. per lineal foot. The horizontal strain from this dead load is therefore

$$\frac{1}{8}\,\frac{1186 \times (216\cdot5)^2}{16 \times 2240} = 194 \text{ tons},$$

and vertical pressure

$$\tfrac{1}{2}\,\frac{(1186 \times 216\cdot5)}{2240} = 57\cdot75 \text{ tons};$$

or with addition of live load at time of accident, 215 and 64 tons respectively. This gives for the strain on the chains (from dead load)

$$\sqrt{\mathrm{H}^2 + v^2} = 201 \text{ tons},$$

and from total load 223·5 tons, or 111·75 tons on each chain.

The original sectional area of chain was 24·4 square inches, so that the strain was 4·58 tons per square inch; but as the material had rusted away to one-sixth of its effective area, the final strain was little short of 28 tons per square inch.

The chamber enclosing the portion of the anchor-chains where the fracture occurred was open to all the surface-drainage of the road. So recently as July 1885 an official inspection had (at the urgent request of the municipality of Mährisch-Ostrau) been made, and the report stated: "The bridge has been examined in all its parts, and is in good and safe condition." The structure being in an important highway will at once be replaced, a temporary bridge having meanwhile been put up.

P. W. B.

On a Bending-Test for Steel Rails. By L. von Tetmajer.

(Stahl und Eisen, 1886, p. 408.)

The Author has made a large series of experiments in the resistance of steel rails to bending-strains, with a view of obtaining some measure of the hardness of the metal, there being no direct method of determining the latter quality. The samples tested were pieces of rails 1·4 metre (4·59 feet) long, which were supplied by the engineers of the four principal Swiss railways, namely, the North-Eastern, St. Gothard, Jura-Berne-Lucerne, and Swiss Central lines. The total number was seventy-one, being partly new rails, and partly those that had broken or worn out in service. The experiments were made with a Werder testing-machine, the strain being applied to the head of the rail, midway between the bearings, which were 1 metre (3·28 feet) apart, by an edge rounded to a diameter of 3 centimetres (1·18 inch), the supporting surfaces being similarly rounded. The deflection was measured by a cylindrical scale (described at p. 96 of the same volume), divided to millimetres and reading to tenths by a vernier. The qualities determined were the bending limit, or the maximum strain not producing permanent distortion, which is analogous to the elastic limit in the tensile test; the deflection under 35 tons load, and the ultimate or breaking limit, which varied from about 35 tons to 54 tons. Diagrams were constructed for each experiment, and measured by a planimeter for the determination of the work of deformation at the different limits. Practically it is not necessary to determine the latter quantity for any strain above 35 tons, as it generally happens that the test-pieces become twisted when this load is but slightly exceeded.

The weights of the rails tested varied from 33·45 kilograms to 37·25 kilograms per metre (67 lbs. to 75 lbs. per yard), with a corresponding variation in the moment of inertia from 894 to 1044·5 centimetres. In order, therefore, to obtain comparative figures, the absolute work of deformation computed from the

observations has in all cases been reduced to an assumed moment of inertia of 1000, giving the so-called relative results of the Tables.

The nature of the observations will be seen from the following examples, extracted from the full report. They refer to rails from the Swiss Central line, weighing 36·8 kilograms per metre (74·2 lbs. per yard), 13 centimetres (5·11 inches) high, and moments of inertia and resistance of 1033·3 and 156·6 centimetres respectively.

Numbers.	67	52	51	60	54	56
Bending-limit . . . . . tons	23·0	27·5	26·0	28·5	33·5	35·5
Breaking-strain . . . . „	41·0	39·8	39·7	47·7	45·0	51·2
Deflection at bending-limit (millimetres, 1 mm. = 0·039 inch) (A)	4·2	5·3	4·5	5·1	5·3	6·2
Deflection at 35 tons . . mm. (B)	5·5	32·9	31·4	21·4	14·8	5·7
„ „ fracture. . „	143·0	131·0	118·0	120·0	111·2	130·0
Work of deformation, centimetre-tons (A)	4·8	7·2	5·8	7·1	8·7	10·8
Work of deformation, centimetre-tons (B)	154·2	93·3	96·9	59·9	41·3	9·9

These figures show that the maximum amount of deflection is 9½ times the minimum, while the maximum work of deformation is 15½ times the minimum, so that the two quantities are not proportional; but the Author considers that the method is likely to be of value in determining the quality of rail-steel, if the assumption that the deformability of rail-steel is directly related to its hardness should be established by experiment. For this purpose, however, experiments on the large scale, continued for some time, will be necessary. The Author has been unable to establish any useful measure of hardness from the resistance of the steel to cutting-tools, a long series of experiments having shown that variations in the effect of mechanical treatment measured the goodness of the tool, rather than the hardness of the metal.

In order to determine the relation between resistance to bending and tenacity, test-pieces, which were subjected to the tensile test in the usual way, were cut from eighteen of the samples, a round bar from the middle of the head, and a flat strip 28 × 12 millimetres (1·1 × 0·472 inch) from the tread of the rail. The results showed that generally high resistance to forcible bending is accompanied by a high elastic limit, and great ultimate tenacity, while the elongation under strain, and contraction on fracture, are correspondingly lowered. The variation in these quantities, on account of the influence of inequalities and faults in the small section of the test-pieces, is, however, by no means so regular as in the bending-test applied to the full section. Thus the limits of tensile strength are 4·3 and 7·1 tons (27·7 and 45·7 tons per square inch) per square centimetre, while the same material,

tested for bending under 35 tons strain, gave differences in deflection between 5·1 and 81 millimetres (0·2 and 3·18 inches), and in the relative work of deformation between 8·9 and 247·9 centimetre-tons. It appears, therefore, that the bending-test is likely to be of more value in determining hardness than the unreliable tensile test.

Out of a total number of seventy-one samples tested, eight, or 11·3 per cent. of the whole, broke under loads varying from 30·5 to 49 tons. Complete analyses, as well as tensile tests, were made of five of these. The former showed that the metal contained too much carbon and phosphorus to be safe, while about half the tensile tests indicated material of high quality.

In conclusion, the Author suggests that the bending-tests should be made at the rolling-mill upon straightened crop-ends of perfect rails, and that it should be applied to the product of particular charges, rather than to a percentage of the finished pile as a whole. In this way it will be more easy to eliminate the result of a defective blow. The following arrangements are suggested for carrying out the test:—

a. Test-pieces to be about 1·2 metre (4 feet) long, perfectly straight, and free from flaws.

b. The distance between the bearings to be 1 metre (39·4 inches).

c. The bearing and pressing surfaces to be knife-edges rounded to a diameter of 3 centimetres (1·18 inch).

d. The pressure to be applied to the middle of the head.

e. A strain of 3 tons per square centimetre (19·35 tons per square inch) in the outermost fibres of the section must not produce any marked permanent deflection. For this purpose the bar is to be subjected for ten minutes to a load determined by the following formula—

$$P = 12 \frac{W}{l} \text{ tons};$$ [1]

W being the moment of resistance of the section, and l the distance between the bearings. When the load is removed, the bar should return to its original shape.

f. The load is next to be gradually increased to a strain of 5 tons per square centimetre (32·25 tons per square inch), taking, where possible, automatic diagrams of the deflection, or measuring the different deflections. The load for this purpose is as follows—

$$P = 20 \frac{W}{l} \text{ tons.}$$

g. Lastly, the strain is to be increased until the bar begins to become permanently twisted, which result must be obtained without any sign of fracture.

H. B.

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[1] The expression tons signifies metric tons of 1,000 kilograms.

Experiments on Waves, and Particularly on the Diminution of Lateral Mean Pressures of the Water undulating in a Canal.

By A. DE CALIGNY.

(Comptes rendus de l'Académie des Sciences, vol. ciii., 1886, p. 107.)

The experiments were made on a canal of rectangular section 1·20 metre (4 feet) wide, 50 metres (165 feet) long, and having a depth of water of 0·40 metre (1 foot 10 inches); one of its extremities entering a large reservoir, the waves produced at the other extremity by a horizontal forward and backward motion produced by means of a water-wheel, were very regular, and died away in the reservoir. The Author proved by means of blades of grass that there was an actual and not only apparent motion of translation as generally supposed, and that the orbital motion of the molecules of water on the upper surface of the liquid acting on tiny rafts pushed these forward so that they arrived in the reservoir long before the blades of grass, which seemed to take part in the general undulation.

Perpendicularly to the first canal was formed a second, separated from the first by a dam, from which passed a zinc tube 0·06 metre (2½ inches) in diameter, and 4·20 metres (13 feet 9 inches) long, flush with the inner side of the first canal, from the bottom of which it opened out, so as not to leave any projecting part. The water fell in the second canal during the undulation of the water in the former, and as it was extensive enough it was interesting to watch the fall of the surface of the water, which rose again gradually when the undulation in the first canal ceased; there was a slight reciprocating motion at the surface of the second canal whilst the water in the first was in motion, which would have been less had the tube been longer.

E. F. B.

Weir and Lock on the Spree at Charlottenburg. By E. MOHR.

(Zeitschrift für Bauwesen, 1886, pp. 207–337.)

These works were constructed in connection with the canalization of the lower Spree, under the Author's direction in 1883–85. They are situated at a short distance below the Charlottenburg railway bridge, near Berlin. The new channel leading to the locks is 1,115 feet long, and 116 feet 2 inches broad in the bed, the level of the latter being 92·19 feet above datum. Two locks have been constructed, the one 285 feet 10 inches long, and the second divided by an intermediate pair of gates into two chambers 164 feet 10 inches and 68 feet 2 inches long, or together 233 feet long; their breadth is 31 feet 6 inches, which is sufficient for two lines of the Finow canal-boats to pass. The locks are constructed

on a piled foundation, with brickwork floors at the entrances 2 feet 3½ inches thick, overlying a timber floor which extends over the whole area and under the side-walls. Each lock was enclosed with sheet-piling from 14 feet 6 inches to 15 feet 6 inches in length, the piles for the foundation being driven to a depth of from 19 feet 8 inches to 23 feet. The level of the lock-sill is 89·24, and the floor of the chamber 88·25 feet. The floor throughout is formed of timber 3 feet thick, resting on the piles and cross-walings. Beneath the floor-timber is a punned layer of small limestone (*kalksteingrus*), 1 foot thick. The lock walls are of blue brick in cement, and 8 feet 6 inches thick at the base.

The filling and emptying of the locks is effected by wrought-iron hatches, which revolve on a horizontal axis placed a little below their centre of figure, and regulated above by a lever; they are as usual placed in the lock-gates and in culverts in the side-walls. A detailed description of the lock-gates is given; they revolve upon cast-steel projections at the back of the heel-post, and the recess is formed in the brickwork and faced with steel-castings. Mention is made of portion of the brickwork and of the stone sill at the entrance to the larger lock being blown up by the pressure soon after being laid; on examination it was found that the timber-flooring and piling beneath had been uninjured. A pipe of 8 inches diameter was driven down through the floor and the run of water tapped, the masonry reconstructed, and the pipe removed after about six weeks, and the hole filled with cement, the flow having gradually ceased in the interval, and no further damage occurred. The total cost of the locks, exclusive of the ground, was £21,050.

The movable weirs, when open, allow altogether a clear waterway of 164 feet, and the level of the bottom of the sluice-way is 90·55 above datum, or that of the river-bed; they are intended to retain the water at its former mean level, viz., 99·74 feet, which during drought, gives a difference of 4·03 feet in the level of the water above and below the weir. Four piers divide the weir into five parts; of these four are 34 feet 5 inches wide, and are occupied by shutter-weirs, and the fifth by a drum-weir 32 feet 9½ inches broad. The drum-weir comprises a vane, or upper and lower paddle, 20 feet 4½ inches, of which 9 feet 8½ inches is above the axis, and 10 feet 8 inches below, and capable of turning through an angle of 90°. The axis is at the level of 90·03 feet, and consequently the crest of the vane when vertical is at level 99·74, and its foot 46·55 feet above datum. When the sluice-way is open, the weir vane is turned to a horizontal position, and lies level with the bottom of the former. The vane is of wrought-iron plate, divided into eight bays of 3 feet 5½ inches, and two of 1 foot 8 inches × 10 inches at each end, by vertical stiffening ribs of angle-iron; it revolves upon cast-iron bearings with a distinct shaft for each bay. The bearings are supported upon a wrought-iron girder stayed by a strut. For the foundations of the drum-weir, the sheet-piling was driven to a depth of 17 feet 2 inches, and then filled up with concrete to a

height of 12 feet 2 inches below the river-bed; upon the latter was constructed the drum-chamber (with a radius of 10 feet 8 inches) in blue brick set in cement, and its interior surface lined with a coating of cement $1\frac{1}{2}$ inch thick; the covering of the chamber is of $\frac{1}{2}$-inch wrought-iron plates supported on rolled joists. This weir is actuated by feeding the water from the up-stream side, through culverts, to either the front or back of the lower half of the vane, which is in the drum-chamber, according to the position desired for the weir to assume; this is regulated by a four-way cock, connecting with the culverts by pipes of $15\frac{3}{4}$ inches diameter.

For the shutter-weirs, the foundations were laid in between sheet-piling, and comprise a layer of concrete 4 feet thick and of brickwork 14 inches thick. The piers are each 4 feet 3 inches thick, and that between the outside shutter-weir and the drum-weir is 6 feet 4 inches thick; they are all built in blue brick in cement, and capped with granite. Each of the four shutter-weirs are divided into five sections; the shutters are of timber, hinged at the top, and raised by hand-wheel with spur-wheel gearing to vertical screwed rods; they are 9 feet 2 inches deep, and the lower portion for a depth of 3 feet is hinged to the upper. After being raised by the vertical screw-gear to the height permissible by that method, the hinges allow of the shutters being pulled up into a horizontal position by chain and windlass.

The footbridge extending across the weir from which the shutters are worked, is raised at the crossing of the drum-weir, and carried by a wrought-iron arch so as to give a headway of 11 feet 2 inches above highest flood-level, and which is sufficient for the passage of the largest Elbe boat. The cost of the whole weir was £9,000. D. G.

The Confluence of the March and the Danube at Theben.

(Wochenschrift des österreichischen Ingenieur- und Architekten Vereines, 1886, p. 315.)

This Paper is a contribution to the study of the navigation of the Danube at an important point, where the main stream is joined by the March, the boundary between Austria proper and Hungary, and above which the conservancy and improvement works are in progress. The March, in its southward flow, impinges on a rocky headland (an outlying spur from the flanks of the Carpathian mountains) a short distance above Theben, and is thence deflected westward of the rocky promontory on which the town is situated, joining the Danube at an exceedingly obtuse angle of back-current, viz., 127°. With varying floods and levels of the two streams, this is the cause of constant accumulation of alluvial deposit and shifting of banks and shoals, presenting great obstacles to the navigation of the Danube. From strategical investigations undertaken

by General von Herman, it would appear that the original course of the March was eastward of the rock, between the fortress and the main street of the town of Theben; and that this headland was therefore on the western bank of the March. By a channel constructed on this original course, to illustrate which plans and sections are given in the Paper, the river would join the Danube by an easy sweep at an angle of about 42°, so that by this confluence of the currents under proper hydrographical conditions, all alluvial accumulation would be reduced to a minimum, and the main stream could be satisfactorily regulated.

P. W. B.

Report of the Commission on the Improvement of the Port of Havre and the Seine Estuary.[1]

A Commission, composed of eight engineers and two naval officers, was appointed by the Government in November 1885, to consider the best means of improving the Port of Havre and the navigable condition of the Seine estuary. The Report of the Commission, presented in May 1886, commences by giving a summary of the various schemes which had been proposed. It next points out that whereas twenty years ago the largest ocean-going passenger steamers did not exceed 390 feet in length, were under 4,000 tons, had an average speed of 12 knots, and did not draw 23 feet of water when fully loaded, now transatlantic steamers of about 8,000 tons are built 525 feet long, having a speed of 15 to 17 knots, and a draught of about 26 feet. It appears probable, from the conditions of accessibility of the most favourably situated commercial ports, that the present limit of draught of 26 feet is not likely to be exceeded. In order to realise the requirements of navigation, the port of Havre should be able to admit vessels drawing 26 feet for eight or nine hours during every tide, and vessels drawing less than 21 feet at almost any time, and should provide shelter and facility of access and departure for large vessels touching at the harbour. Rouen, being an inland port, would possess adequate accommodation for ordinary trade if the passage through the estuary could be rendered secure, and could be increased about 3 feet in depth. The port of Honfleur is chiefly devoted to the timber trade, which is carried on by steamers of 1,000 to 1,500 tons, drawing from $14\frac{3}{4}$ to 19 feet of water, so that its wants would be supplied by a permanent channel to it through the estuary, with a minimum depth of $19\frac{2}{3}$ feet at high-water ordinary spring-tides. After describing the tidal conditions of the sea-board of Havre and in the estuary, the changes in the estuary, and the existing state of navigation up to Rouen,[2] the report sets forth the works proposed by the

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[1] The original is in the Library Inst. C.E.
[2] Minutes of Proceedings Inst. C.E., vol. lxxxiv. p. 241.

Commission. The works recommended for Havre consist of a large outer harbour formed along the sea foreshore between the present port and Cape la Hève, with an entrance at the north-western corner outside the estuary, and communicating at the south-western corner with an extension of the present entrance harbour, having an outlet into deep water in the line of the existing approach. Provision is also made for large additional docks along the foreshore of the estuary to the south of the Eure and Ninth Docks, which are to be connected with the enlarged entrance-harbour by locks capable of admitting vessels of the largest size; a deep channel is to be dredged through the approach-harbours leading from the northern entrance to the new locks; and three shoals outside, in the lines for approaching the entrances, are to be lowered. The works proposed for the estuary consist in the deviation of the existing trained channel between Tancarville and Berville by the construction of new training-walls in a more northerly direction, and wider apart, and the prolongation of the training works in a serpentine course down to Honfleur. The trained channel, 1,640 feet wide at Tancarville, is to widen out to 2,950 feet opposite La Roque, at which point the River Rille is to be led into the Seine through a diverted channel. Where the course of the channel, which is convex towards La Roque, changes its curvature about half-way to Berville, its width is reduced to 2,790 feet; and it widens out again gradually to 4,430 feet a little past Berville, narrowing again to 4,265 feet at the next change of curvature opposite Fatouville, from whence it widens out rapidly to 9,840 feet at the end of the trained channel alongside the entrance channel to Honfleur. The outer portion of the northern training-wall, between the meridians of Ficquefleur and Honfleur, is to be kept low, so as not to interfere with the free admission of the flood-tide; but the rest of the walls are to be high walls. It is considered by the Commission that the sinuous course will secure a fixed channel along the concave banks, and that the reduction of width at the changes of curvature, where the channel crosses over, will reduce the shoals which would naturally form at these points; and the concave bank along the Honfleur foreshore is designed to secure a permanent entrance channel to the port by leading the deep channel in front of the entrance jetties. The total cost of the works proposed for Havre, including the protection of Cape la Hève by groynes to stop the encroachment of the sea, is estimated at £4,560,000; but an expenditure of £2,520,000 would supply all present requirements, leaving the finishing off of the northern outer harbour, and the construction of the new docks, to a future period. The cost of the estuary works, together with the removal of shoals above Quillebeuf, is estimated at £1,000,000. It is believed that the proposed estuary works, giving equal facilities of access from the sea to Honfleur and Rouen, will only leave a single narrow shoal to be traversed, much lower than the existing shoals in the estuary, and will neither materially reduce the capacity of the estuary, nor

present an obstacle to the free circulation of the currents in all the lower part of the estuary. By the simultaneous execution of the two sets of works, Havre would be provided with a deep entrance beyond the estuary by the time the training works were completed, so that it would be secured against the effects of any accretions that might eventually result from these works. A deep-water entrance is essential for Havre if it is to retain its ocean trade, for whereas, between 1878 and 1884, the tonnage of entering vessels increased 65 per cent. at Hamburg, and 46 per cent. at Antwerp, the increase was only 6 per cent. at Havre during the same period. L. V. H.

On the Works undertaken in Tunis by Commander Laudas on the death of Colonel Roudaire.

By Sir F. de Lesseps, Hon. M. Inst. C.E.

(Comptes rendus de l'Académie des Sciences, vol. ciii., 1886, p. 311.)

After spending many years in levelling, boring and experiments of various kinds, Colonel Roudaire satisfied himself that the four shotts, Tedjedj, Djerid, Rharsa and Melrir, to the south of the chain of the Leures, situated 24 metres (77½ feet) below the level of the sea, could by means of a canal be formed into an inland sea, thus influencing the climate and fertility of these countries to a considerable degree, the area being 8,200 square kilometres (3,164 square miles) or forty times that of the lake of Geneva. Owing to the expense involved, however, another point of departure has been effected. From the discovery of Roman aqueducts formerly employed in irrigation, the idea occurred of cultivating the surrounding country, irrigating it by means of artesian wells, and employing part of the rents in the excavation of the canal destined to inundate the Melrir and Rharsa shotts. The first well was started in May 1855; at a depth of 90 metres (295 feet) water was found, which rose to a height of 4·7 metres (15 feet), the flow from May 1885 to June 1886 was on an average 8,000 litres (1,760 gallons) per minute, and is now 9,000 (19,800). The banks of the river Melah, which fifteen months ago were deserts, are now populated, and very shortly the canal is to be commenced. Marshal Bugeaud is reported to have said that the civilization of the French African possessions would come from below, that is, would depend upon the subterranean water-supply.

E. F. B.

On the Interchange of Water between the Black Sea and the Mediterranean. By Capt. MAKAROFF, I.R.N.

(Zapiski Imperatorskoi Akademei Naouk [Journal of the Imperial Academy of Sciences], 1885, vol. 51.)

After a brief review of the knowledge hitherto existing respecting ocean currents in general, and the flow of water between the Black Sea and the Mediterranean in particular, and after dwelling especially upon the remarkable observations of Marsilii in 1681, the article proceeds to examine the investigations and experiments carried out by the Author after the year 1881. Having first, by a few preliminary experiments, satisfied himself of the existence of an upper and lower current in opposite directions between the Sea of Marmora and the Black Sea, he proceeded to organize a series of systematic and exact measurements of the temperature, specific gravity, and velocity of the water at various depths. The two former properties were ascertained by means of carefully verified instruments, while the velocity was determined by an apparatus specially contrived by Captain Makaroff, and named by him the "fluctometer." It consisted of an ordinary two-bladed screw propeller, mounted on a rudder frame and fitted with a bell fixed to the screw spindle and revolving with it. The clapper of the bell oscillated on a pivot at right angles to the axis, so that, in turning, it would fall over and give a blow twice in each revolution; one blow was deadened by india-rubber so that the bell emitted the sound of one stroke in each revolution. It was found that the sound could be plainly heard and the revolutions counted, when the observer was in the hold of the ship. This apparatus was lowered by a wire rope 1 inch in circumference, with sinkers arranged at different depths so as to take advantage of the opposing currents to keep the instrument approximately vertical. The other instruments were lowered by means of Sir William Thompson's wire-sounding apparatus. Some four thousand observations were made, at various times and seasons, on the temperature and specific gravity of the water, and about one thousand on the velocity of the currents.

The following Table (see next page) is a specimen of the thorough manner in which the work was done off Constantinople, 15½ miles from the Black Sea.

The general conclusions arrived at by Captain Makaroff are as follows:

1. The waters of the Mediterranean are heavy (specific gravity 1·030) and warm, between 13° and 27° C. at the surface, and at a constant temperature of 13° C. 200 fathoms down. The surface of the water is below the mean level of the sea.

2. The waters of the Black Sea are light (specific gravity 1·013 at the surface and 1·016 at the bottom) and comparatively cold, the temperature in the summer time, below a depth of 80 fathoms, is constant at 10° C. At the surface the temperature rises to 25° C.

6 o'clock P.M., July 31.				Average of Thirteen Series of Measurements.	
Depth of Observation below Surface in Fathoms.	Number of Revolutions of Velocimeter.	Temperature of the Water in Degrees Centigrade.	Specific Gravity of the Water.	Specific Gravity of the Water.	Velocity of Current in Knots.
0	47	23·6	1·0157	1·01507	2·38
1	45	23·6	1·0155	..	..
2	44	23·5	1·0153	1·01507	1·95
4	31	22·9	1·0158	1·01520	1·57
6	30	22·6	1·0161	1·01541	1·27
8	21	22·6	1·0155	1·01575	0·98
10	12	22·4	1·0161	1·01628	0·71
11	0	22·0	1·0184	1·01733	0·00
12	5	19·2	1·0272	1·02068	1·04
13	26	19·2	1·0258	..	..
14	28	18·0	1·0303	1·02748	1·42
16	24	17·5	1·0306	1·02964	1·26
18	22	17·2	1·0314	1·03048	1·12
20	14	17·2	1·0318	1·03100	1·00
22	13	16·8	1·0314	1·03135	0·81

At 8 o'clock p.m. July 31.

Wind, N.E.	– 3
Barometer	30·08 inches.
Temperature of air	26·2 ° Centigrade.

and sinks in winter to 6° C. The level of the surface, on account of the excess poured in by the rivers over the loss by evaporation, and on account of the lower specific gravity of the water, is higher than that of the Mediterranean.

3. The waters of the Mediterranean penetrate into the Sea of Marmora by an under current reaching from 6 fathoms below the surface to the bottom, while a current sets in the opposite way along the surface; the boundary between the currents gradually sinks from 6 fathoms in the straits to 10 fathoms below the surface in the Sea of Marmora.

4. Two currents exist also in the Bosphorus. A lower one, composed of heavy and comparatively warm water setting in towards the Black Sea, while a counter current of light and cold water flows in the opposite direction. The boundary between the currents slopes from 10 fathoms opposite Constantinople to 27 fathoms below the surface at the entrance to the Black Sea.

Captain Makaroff has attempted to estimate the volumes of water passing in and out of the Black Sea, but is constrained to admit that sufficient data have not yet been collected to allow of trustworthy calculations.

The Paper is illustrated by a map, on which the points of observation are marked, by drawings of the apparatus used, and by sections and curves showing the reduced observations graphically.

W. A.

The latest Survey for the proposed Nicaragua Canal.

By Geo. J. Specht.

(Wochenschrift des österreichischen Ingenieur- und Architekten-Vereines, 1886, pp. 267 to 270, and 275–277.)

This survey was made in 1885, by A. G. Menocal, of the United States Navy, and the report submitted by him, of which this Paper is an abstract, includes notices of previous surveys made in 1872–73 and 1880.

The proposed Canal will connect the port or harbour of San Juan del Norte or Greytown on the Atlantic with that of Brito on the Pacific Ocean. Its total length is nearly 170 miles, of which about 40 miles are canal proper, the remaining 130 miles being formed by channels in the Nicaragua Lake, and portions of the rivers San Juan and San Francisco and their tributaries.

The line is divided into three sections namely *The Western Section* which extends from the mouth of the River Lajas on the west side of Lake Nicaragua, to Brito on the Pacific. Its length is about 17 miles, and with the exception of short reaches of the Rivers Lajas and Grande is canal proper. The mean water-level of Lake Nicaragua is taken as the summit level of the canal, and the fall from this to the Pacific is got over by four locks with lifts of from 25 to 30 feet.

The Eastern Section comprises 19 miles of canal proper with two locks of 27½ feet lift, and one with a lift of 53 feet.

The Middle Section connects the eastern and western sections, and comprises 57 miles of channel in Lake Nicaragua, 64½ miles in the San Juan River, 8½ miles in the valley of the San Francisco, and 3½ miles of canal proper.

The bottom breadth of the canal varies from 80 feet in rock-cutting to 125 feet in the dredged out channel of the River San Juan, and 150 feet in the channel through Lake Nicaragua.

Blasting under water will be required for 800 yards in the above lake, and for about 24 miles in the San Juan river.

Just below the point where the canal takes off from the San Juan (64 miles below its outlet from Lake Nicaragua) a dam 420 yards long, and 52 feet high is proposed to be built, which will head up the water right back to the lake. Another very large dam 2,000 yards long, and 51 feet high, will be built across the San Francisco valley, and between these two, at a point where the canal crosses a narrow but deep tributary of the San Juan, a small dam will be necessary.

The locks are 650 feet long, and 65 feet wide, with lifts of from 25 to 30 feet, except the first lock in the eastern section, which has a lift of 53 feet. This lock is to be blasted out of the solid rock and lined with concrete, but all the other locks will be built entirely of concrete.

The lock-gates generally are of iron, and capable of being slid

or drawn back into side recesses; but the lower gate of the lock alluded to above with a lift of 53 feet is of a different construction designed by engineer R. E. Peary of the United States Navy. This gate, 88 feet high, is a roller-gate running on rails, the lower part being in the form of a quadrant, and, by means of hydraulic machinery a traveller placed on the top of the lock, can be raised and run into a niche in the side, specially constructed for the purpose. (Plan and elevation of this gate with description of the method of working it are given in the Paper.) The advantages claimed for the design are rapidity and simplicity of working, and easy accessibility to all parts of the gate, so that any necessary repairs can be carried out without stopping the service of the lock.

As regards water-supply, careful measurements of the discharge in the San Juan river, both at ordinary and flood levels of the lake, give a mean of 14,755 cubic feet per second, or 47,180,000 cubic yards per diem. The total daily requirements for lockage, on the supposition that thirty-two vessels pass through, is 4,776,640 cubic yards, so that there is a daily excess-supply of over 42,000,000 cubic yards, the loss from leakage and evaporation being taken as compensated by the supply of the tributaries of the San Juan and San Francisco rivers.

The time of passage through the canals and locks is estimated at thirty hours, or an average speed of 5·7 miles an hour, and it is stated that the canal would admit of a traffic of 20,000,000 of tons per annum, assuming the average tonnage of vessels passing through to be the same as in the Suez Canal.

The mean rainfall is given as 50 inches on the west side of Lake Nicaragua, where the rainy season continues from May to November or six months; but on the east side, that is, in the San Juan district, the rainy season lasts longer, and the total rainfall may be taken as 80 inches. During this season the water in the lake frequently rises 110 feet above mean-level, the ordinary depth of the lake as of the canal generally being from 28 to 30 feet.

At both ends of the canal it is considerably widened, so as to extend the harbours of Greytown and Brito. Building materials of all kinds are found conveniently near the line of canal; wood of excellent quality grows on the west side of the lake, and on the slopes of the San Juan and San Francisco valley basins. Limestone is found at several places; good sharp sand and gravel in abundance in the bed of the Rivers Grande and San Juan, and at many places good brick-clay is met with.

The total cost is estimated at £12,808,740, and the time of completing the work six years, including one year for the detailed trace and the necessary preliminary operations.

A plan and longitudinal section of the proposed canal, with the eastern and western locks on a larger scale, accompany the Paper. W. H. E.

Nicaragua Ship-Canal. By S. Foster Crowell.

(Proceedings of the Engineers' Club of Philadelphia, 1886, p. 327.)

At a previous meeting the Author had reviewed the three projects for inter-oceanic communication. "The Panama Canal, if completed, will be a through cut at the sea-level." "The Ship-Railway, *per se*, is to be continuous from ocean-level to ocean-level, so far as we are informed by its designers."

The Nicaraguan scheme, in its modified form, is of composite character. The Author's labours in the surveys prior to 1874 familiarise him with the region where he spent two years of active work. The word canal, as generally used, is a misnomer for the project, which is a slack-water system of grand dimensions, wherein lake and river navigation, practically unrestricted, constitute $129\frac{8}{10}$ miles, or 77 per cent. of entire passage; the artificial channels aggregate only 40 miles, or 23 per cent.; the entire transit being $169\frac{8}{10}$ miles.

Of the artificial channels, more than 13 miles "will be of such width and depth as to deprive them of any objectionable restriction, leaving only an aggregate length of 27 miles divided into several separate stretches of confined canal. Lake Nicaragua, 90 miles by 35 to 45 miles, has about 8,000 square miles drainage area, the isthmus separating the lake from the Pacific, 12 to 15 miles wide at its narrowest, where the mountain-range forming back-bone of entire isthmus has its 'lowest notch,' the location for western section of canal. At the north-west end of the lake, entering the small river Tipitapa, an overflow for Lake Managua, which is 15 feet higher than Lake Nicaragua, which is 110 feet above ocean mean-tide." The only break in the mountains bordering the basin on the south, north and east, is at the extreme eastern end of the lake, and through it the San Juan river flows towards the Atlantic, the sole outlet of the lake. The San Juan valley is a prolongation of the basin, hemmed in by mountains down to the San Carlos river, 64 miles from the lake, where the summit-level dam is to be formed below this river's mouth at Ochoa, where the valley narrows: 9 miles below the dam another river, the San Francisco, enters the San Juan from the north, formed of two branches. Across the river, between the forks and the San Juan, a second dam, the same height as the Ochoa dam, is to be thrown, and the "divide" between the rivers Machado and the San Francisco will be passed by a stretch of canal, and reaches the site of the upper lock on the Atlantic side of the lake, the length of the cut being 14,200 feet, with an average depth of cutting of 147 feet above the bottom of the canal, constituting the heaviest work on the entire line. This lock (No. 3) carved in a rocky spur of the northern hills, is the eastern end of the summit-level, which stretches back through the San Francisco basin, up the San Juan, and across the lake to the first lock on the west side, a distance of $144\frac{8}{10}$ miles. This rock-

hewn lock drops the canal 53 feet into the valley of the Descado; 4,600 feet further is another lock, with a drop of 27 feet, and thence the line follows the widening valley, 1,500 feet further to the third and last lock, which, with a drop of 26 feet, brings the canal to the sea-level. From this lock to Greytown harbour, a distance of 61,000 feet ($11\frac{6}{10}$ miles), the course is direct across the low, flat basin of the sinuous San Juanillo, and through the lagoon districts, the average of which is 10 feet above tide.

On the west side of the lake, the summit-level is carried through the "divide" at the mouth of the river Lajas to 4·7 miles from the lake; the canal then continues $1\frac{3}{4}$ mile to the Rio Grande; follows its upper valley for $1\frac{1}{2}$ mile; reaches the first of the locks where the summit-level ends, and the canal sweeps down the broad valley of the Rio Grande, dropping by three more locks 26·4 feet to 29·7 feet lift, to the sea-lock at lock No. 7, 1·4 mile inland from Brito. There the canal practically ends, as from this point to the sea it is so enlarged as to form an extension of the harbour. The excavation is mainly sand and gravel, but in the "divide" it is rock, which is intended to be utilized in the Brito breakwater, pitching the canal-slopes, &c. The lake for 56·50 miles, from the river Lajas to Fort San Carlos, at the head of the San Juan, carries 28 feet, except at two ends where dredging is required.

The details of dams, locks, Brito basin, and Greytown harbour are described.

Locks.—The locks proposed are "magnificent structures," 650 feet × 65 feet × 29 feet over the sills, big enough for the "City of Rome," or the "Acapulco" and "Colon" together — seven in all; to have iron sliding-gates, retreating into a lateral recess when open. For the tail-gate of lock No. 3, 88 feet in height, a rolling gate of novel design, travelling on top of lock, connected to the gate by a long "strut or pitman rod." Water-ballast to be used; adjusting chains, &c., and motion to the car, "by a compound air or hydraulic motor."

The Harbours.—The Author points out the great advantages offered by the lake itself for refitting, &c., and says: "Situated in a magnificent and healthy country, with immunity from continued gales and ample shelter, this beautiful inland-sea is ready and waiting this, its most appropriate use."

Adequate protection for the canal-entrances all that is demanded.—The proposals of 1872–73 in this respect being adhered to, save the change for the tidal lock at Brito from the inner end of the harbour to a position 1·4 mile inland.

A jetty is proposed at Greytown, and a breakwater at Brito, but this last may possibly be dispensed with.

As regards dimensions and capacity, he glances at the inability of the Suez Canal to accommodate a traffic of more than 6,000,000 tons per annum, with delays due to dimensions and insufficient number of crossing places. Only $12\frac{6}{10}$ miles of the Nicaraguan line exist where the prism is not sufficient for vessels to pass, and not continuous but sub-divided, and situate between lock basins

and could be traversed in less time than required for lockage, and will not be a cause of delay.

After referring to statistics of the Suez Canal traffic, the Author says:—"These facts show conclusively that vessels of 4,400 tons, 400 feet long, 52 feet beam, and 22 feet draught, can go through the Suez Canal at an average speed of 6 statute miles per hour, and smaller ones at 6 to 8 miles per hour, and the experience shows that the actual time of transit is not likely to exceed these figures."

Of the estimated time and amount of traffic, the Author says: "On the above basis of forty-five minutes for lockage, and allowing but one vessel per lockage, thirty-two vessels can be passed per day, or eleven thousand six hundred and eighty per year, which, with the average net tonnage at Suez, gives a yearly capacity of 20,000,000 tons."

The Paper concludes with statistics to show abundance of water supply; and of probable cost, giving a grand total of \$64,043,669.

J. B. R.

A Method of Blasting without Explosives. By Dr. Kosman.

(Oesterreichische Zeitschrift für Berg- und Hüttenwesen, vol. xxxiv., 1886, p. 178.)

The Author proposes in blasting in fiery mines to substitute for gunpowder, dynamite, and other explosives requiring ignition, cartridges containing zinc dust (the mixture of finely-divided zinc and zinc-oxide that collects in the condensers of the zinc retorts), and diluted sulphuric acid. The cartridge-case is a glass cylinder, 7 inches long and 1 inch in diameter, closed at the bottom, and divided into two parts, whose volumes are in the proportion of 1 to 4 by a choking or contraction which reduces the bore at the junction of the two chambers $\frac{3}{10}$ or $\frac{4}{10}$ of an inch. The lower or larger division is filled with diluted sulphuric acid, and the contracted opening is stopped with a plug of cork, india-rubber, or asbestos, in which state it is given to the miner. When required for use, the upper part of the case is filled with zinc dust, and the shooting-needle is passed through it into the plug closing the acid-chamber. The shot-hole is loaded and tamped in the ordinary way, first with tempered and then with dry clay or broken-up shale. If the rock is porous or jointed the hole should be carefully clayed, to prevent the gas escaping through the cracks. The shot is "fired" by one or more smart blows on the shooting-needle, which drives in the plug and breaks the glass at the choked part, when the zinc-dust mixes with the acid, and a rapid, although not instantaneous, evolution of hydrogen takes place whose expansive power is sufficient to break down the rock. The following figures are given as a measure of the power available:—A cartridge of 25 millimetres in diameter, and 180 millimetres long, is approxi-

mately of the capacity of 90 cubic centimetres. The charge consists of 50 cubic centimetres of sulphuric acid and 12 grams of zinc-dust, which, according to its average commercial composition, will contain about 10 grams of metallic zinc.

According to the formula, $Zn + H_2 SO_4 = Zn SO_4 + 2 H$, 10 grams of zinc will liberate 0·3 gram of hydrogen, or by volume 3·37 cubic metres (1 cubic metre of hydrogen at 760 millimetres barometer pressure weighs 0·089 gram). This volume of gas being confined to 90 cubic centimetres, the resulting pressure will be $\frac{3,370,000}{90} = 37,000$ atmospheres in round numbers. This is computed at zero, but at higher temperatures, such as prevail in mines, the pressure will be notably greater. In blasting with gunpowder the pressure developed is below 5,000 atmospheres. The production of the cartridge-cases has been entrusted to a single firm, in order to obtain uniformity in the manufacture. The cost of a shot will vary with the calibre and weight of the charge, from about 1½*d.* to 2*d.* The question whether danger might be apprehended from the sudden addition of a large volume of hydrogen to the air of mines already containing inflammable gas must, the Author thinks, be answered in the negative, as hydrogen diffuses so rapidly in atmospheric air that the power of inflaming is soon dissipated. For instance, if zinc-dust is covered with diluted sulphuric acid in an open dish of 500 cubic centimetres capacity the gas cannot be fired by a naked light at the edge of the dish, and the flame must be applied to the bubbles of hydrogen as they form to obtain a detonation. This rapidity of diffusion is likely, therefore, to prevent any danger by the addition of hydrogen to the air in mines which are well ventilated and worked with safety-lamp. The heat developed by the action of the acid upon the zinc also causes a considerable development of steam, which, mixing with the gases, acts in diminution of the explosive power. These and other points can, however, only be settled by experiment on the large scale.

H. B.

The Longest Tunnel in the World.

(Wochenschrift des Oesterreichischen Ingenieur- und Architekten-Vereines, 1886, p. 284.)

According to the "Bauzeitung für Ungarn" the longest tunnel in the world is at Schemnitz, the oldest and most important mining town in Hungary. This tunnel was completed in 1878, and is 10·27 miles long, being thus 1 mile longer than the St. Gotthard, and more than 2½ miles longer than the Mont Cenis tunnel. Its construction was agreed upon in 1782, in order to carry off the water in the mines to the lowest point of the Gran Valley, and borings were first made at Wornitz, a village on the left bank of

the River Gran, and distant 10 miles west of Schemnitz. The height of the tunnel or adit was fixed at 9 feet 10 inches, and breadth 5 feet 3 inches.

According to the original agreement, the work should have been completed in thirty years, at a cost of £121,500. This would give about £7 as the cost per lineal yard, and for the first eleven years the work was done at this price. But after the French Revolution the cost of labour and material was so high, that for the next thirty years or more but little progress was made, and the cost per yard rose to £34. Then came a period of ten years of great activity, followed by a lull for the next twenty years, when the ever-increasing volume of water threatened the existence of the mines and called forth exceptional efforts, and the work was pushed forward at the rate of 320 yards per annum for twelve years at a cost of about £22 per yard. For the next five years the work flagged again, until in 1874 a yearly credit of £15,000, guaranteed by the Hungarian Government, gave the work new life, and the newly invented and improved boring machines and means of blasting expedited operations considerably.

The total cost of the tunnel has been nearly £1,000,000, but the results are said to justify the expenditure, and as the adit is quite 60 yards lower than the lowest point to which the lode vein has been penetrated, all water-lifting machines can be dispensed with, and this represents an annual saving of £15,000.

W. H. E.

Technical Uniformity on Railways.

(Revue Générale des Chemins de fer, June 1886, p. 423.)

In October 1882, the first International Conference for Technical Uniformity on Railways, was held at Berne; and the second was held in May 1886, with the view of settling some questions which had been held in suspense, attended by delegates from Germany, Austria, Hungary, France, Italy, and Switzerland.

The first and principal question related to the way and the rolling-stock, as to which the following recommendations were adopted, subject to their being ratified by the several Governments represented:—

The gauge of the way, for new lines and for renewals, is to be 4 feet $8\frac{1}{2}$ inches, except in curves, where the gauge is not to exceed 4 feet $9\frac{1}{16}$ inches.

The rolling-stock of the railways are not to be excluded from international circulation, when they accord with the following conditions:—

The extreme distance apart of the axles of goods wagons, to be constructed at least 8 feet $2\frac{1}{2}$ inches from centre to centre; the width apart between the backs of the wheels on one axle, from 4 feet $5\frac{1}{4}$ inches to 4 feet $5\frac{7}{16}$ inches; width of the tyres, from

5·91 inches to 5·12 inches; play of the flanges, from 1·38 inch to 0·60 inch; height of the flanges, from 1·42 inch to 1 inch; thickness of the tyres, minimum, $\frac{13}{16}$ inch; chilled cast-iron wheels, without breaks, are admitted, to run at speeds not exceeding 28 miles per hour; all carriages and wagons to be fitted with buffing and draw-springs; the centres of buffer-heads of vehicles, when empty, to stand from $3\frac{1}{2}$ feet to 3 feet 4 inches above the level of the rails; the height, when loaded, at least 3 feet 1 inch; the distance apart, horizontally, of the centres of the buffer-heads, from 5 feet $9\frac{1}{4}$ inches to 5 feet $7\frac{3}{8}$ inches; diameter of the buffer-heads, 13·4 inches; play of the buffers, $11\frac{3}{4}$ inches; projection of the buffers beyond the draw-hook, 16 inches to $11\frac{3}{4}$ inches; extreme extent of the couplings beyond the buffers, $21\frac{1}{2}$ inches to $17\frac{3}{4}$ inches; diameter of the section of the coupling-link in contact with the draw-hook, $1\frac{3}{8}$ inch to $1\frac{3}{16}$ inch; minimum tolerated for carriages, $\frac{7}{8}$ inch; for wagons, 1 inch; clear height of the coupling-gear hanging down above the level of the rails, loaded, 3 inches; brake-handles to turn from left to right, like the hands of a watch, when being screwed up; the look-outs on vans to be 16 inches clear within the plane of the buffer-heads when screwed up. A double key is provided for opening and closing the carriages engaged on international transit: one end being a socket, and the other end a square; and the locks of carriages are to correspond to one or other of the two forms of key. Other regulations apply to the closing of carriages and wagons in passing the customs.

D. K. C.

Notes on the Failures of Locomotive Crank-Axles.

By E. SAUVAGE, Mining Engineer.

(Annales des Mines, vol. ix., 1886, p. 335.)

Locomotive axles are liable to failure by fracture through the bearings, the crank-webs, or the crank-pins. Of these, the first-named is the most rare, and the last the most common, the fracture usually taking place at the juncture of the crank-pin with the web. Sometimes it actually occurs during work; but more often the axle is condemned on account of an incipient fracture before it actually takes place.

On the Northern Railway of France, during the five years 1881–85, there were fifty-eight cases of breakage; one in the bearing, five in the web, and fifty-two in the crank-pin. Of these last, thirty-six were in the right-hand pin, as against twelve in the left-hand pin, while four were not specified; and no satisfactory reason for this discrepancy has yet been assigned. During the same period one hundred axles were condemned, ninety-three for cracks, and seven for strained journals and other causes. It is a matter of considerable delicacy, and one that depends a good deal

on the individual judgment of the inspector, to pronounce whether a flaw, real or supposed, is of itself sufficient to justify the condemnation of an axle.

Various methods of strengthening crank-axles have been proposed, the chief value of such contrivances being not so much the actual prevention of rupture, as the diminution of danger from resulting damage, by the retention of the fractured parts in their relative positions, thus converting the broken axle into a sort of built-up axle, while there is no longer the same necessity for condemning an axle so strengthened on account of a slight flaw, which may be of no real moment. The webs may be strengthened by shrinking upon each of them a band or hoop, which for an axle of ordinary dimensions, say $7\frac{1}{2}$ inches diameter in the body and $7\frac{7}{8}$ inches diameter at the crank necks, may be about 4 inches wide × $1\frac{3}{8}$ inch thick. The crank-pins, where fracture most frequently occurs, might, it is true, be strengthened by giving them an increased diameter; but this would not only entail an increased size of the big-ends of the connecting-rods, already inconveniently large, but would also necessitate raising the boiler-barrel in a corresponding degree. By drilling an axial hole $2\frac{3}{8}$ inches diameter through each crank-pin, it would be weakened to a very slight extent, while the insertion of a bolt would enormously add to its safety; and as such a bolt would be exposed only to a shearing, and not to a tensile strain, its full area, and not the reduced area at the bottom of the thread, would be available. If necessary, both the head and nut of the bolt may be sunk into the body of the crank-web, the material of which, at those points, is not exposed to any strain. The cost of the four hoops shrunk on the webs is £5; that of drilling and bolting the two crank-pins is £1 12*s.*; and this extra cost is fully repaid by the increased life of the axle.

The Paper is illustrated by an engraving showing the method of hooping and bolting a crank.

W. S. H.

Ballast-Excavator with Cylindrical Sifter. By J. Michel.

(Revue Générale des Chemins de fer, August 1886, p. 99.)

For the last fifteen years the engineers of the Paris, Lyons, and Mediterranean Railway, have recognized the necessity of maintaining the ballast completely permeable, in good condition, like the rails and the sleepers. The packing of the sleepers, their duration, as well as that of the rails, are dependent on the good quality of the ballast. Vast gravel quarries have been opened in the neighbourhood of the railway, and the sand found in mixture with the gravel has been sifted by hand, in the same manner as the sifting of the old ballast is done.

Recently, one of the contractors for ballast for the line from

Lyons to St. Étienne—Mr. Delamarre—has erected an excavator in the Pierre-Bénite quarry, near Oullins, fitted with a sifting-cylinder, constructed of longitudinal rods ⅝-inch in diameter, spaced ½ inch apart, which is caused to rotate, by means of which the excavated gravel may be sifted of sand and earthy matter, as it is raised, and discharged in good condition. The ordinary slide is dispensed with. This excavator has sixteen buckets, worked by means of a steam-engine of 25 HP.; the capacity of each bucket is about 2⅓ cubic feet. The sifting-cylinder is 7¼ feet long, 3 feet 7 inches in diameter, driven by a Galle-chain and a belt. It is inclined at an angle of 1 in 6½, and makes thirty revolutions per minute. By means of a cam movement, the cylinder is struck by four hammers alternately in succession, each giving fifteen blows per minute, thus shaking off what rubbish may adhere to the cylinder. The sifted gravel falls into wagons placed to receive it. The detritus which passes from the cylinder falls into a slide placed below, and thence into a separate wagon, and is carried away and deposited partly in stock, and partly to help to fill up the gaps made by the excavator.

The excavator is mounted on a truck, and may be moved forward or backwards, or may be swung through one-third of a circle by means of a small steam-engine on the truck. These movements are effected by means of Galle-chains worked by toothed gearing and an endless screw. The cylindrical sifter can be readily moved out of the way when required, and replaced by the plain slide for ordinary excavating.

There is, at the Pierre-Bénite quarry, about 35 per cent. of detritus or sifting from the gravel. As sixteen buckets, holding about 2·12 cubic feet of stuff, are emptied per minute into the cylinder, a total of 2,035 cubic feet is raised per hour, of which 35 per cent., or 712 cubic feet, is débris, and 1,323 cubic feet is ballast. Eight hours a day of effective work with the machine produces 10,584 cubic feet of ballast per day. To sift 14,110 cubic feet twenty-five sieves are required, each employing two men to work it, besides eight men to remove the detritus, causing a daily expense of upwards of £7. The excavator cost £5,200, and it is estimated that a saving of 0·44*d.* per cubic yard is effected by its use.

D. K. C.

Beating- and Brushing-Machine for Carpets and Cushions of Railway Carriages. By Charles Bricogne.

(Revue Générale des Chemins de fer, July 1886, p. 25.)

The machine for beating the cushions and carpets of railway carriages is employed at the new workshops of the Northern Railway of France, at Hellemmes-Lille.

The cushions are beaten and brushed at the same time. They

are brushed by means of two revolving cylindrical brushes, about 10 inches in diameter, the axes of which are parallel to the centre line of the machine, under which they are passed. They are beaten by twelve leather straps, fastened in pairs on the rim of a drum, 20 inches in diameter, 75 inches long, making three hundred revolutions per minute, the axis of which is at right angles to that of the machine. The brushes are placed about 50 inches apart between centres, and the cushions are beaten in the space between the brushes, which is traversed by them four times, twice one way, twice the other way. They are pushed by hand, one behind another across the machine, on a flat board, the level of which is adjustable for the varying thicknesses of the cushions. The brushes revolve in opposite directions, so as to drive the dust into the interspace, whence it is removed by a ventilator.

To beat the carpets the brushes are not used. The beating straps only are employed, and the drum is adjusted to the level of the carpets, which are placed on endless chains, by which they are advanced under the beaters. The carpets pass from the beaters and are returned to the feet of the attendant. The machine is completely enclosed in a glass chamber, about 10 feet long, 6½ feet wide, 7 feet high, by which the attendants are protected from the dust, which is removed by a Bourdon ventilator outside.

With this machine three hundred carpets or cushions can be cleaned in the course of ten hours with two men, whose wages are respectively 3*s*. 7*d*. and 3*s*. 2*d*. per day; making the cost of cleaning an average of 0·27*d*., or a little more than ¼*d*. per piece, for wages. By hand, the cost for cleaning amounts to about 4*d*. per piece in wages, as two men cannot well clean more than two pieces per hour. The work is incomparably better done by the machine.

D. K. C.

The Employment of Salt for the Removal of Snow.

By — Barabant.

(Annales des Ponts et Chaussées, 6th series, vol. xii., 1886, p. 273.)

In 1880 Mr. d'Ussel gave a description of his first attempts to thaw the thin layer of ice in the public streets, produced by the compression of snow by vehicles in time of frost.[1] Since that period, owing to the expenditure of nearly £200,000 in futile attempts to remove the snow in Paris in 1879–80, and 1880-81, the heavy tax has been removed from pounded salt, not suitable for ordinary purposes, enabling salt to be largely used for clearing away snow, a provision of 4,000 tons of salt having been made for this purpose

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[1] Annales des Ponts et Chaussées, 5th series, vol. xx. p. 553.

in Paris for the winter of 1885–86. A regular service for the removal of snow, on its first appearance, has been organized in Paris, as it is important to clear away the snow before it has been compressed into ice by the passage of vehicles, when it is far more difficult to remove. As falls of snow rarely occur at Paris with a temperature much below the freezing-point, salt may be sprinkled on the snow, producing a liquid, of which the temperature may descend to 5° Fahrenheit without its freezing. The salt should be scattered on the streets as soon as the snow begins to fall fast; the mixture is effected more thoroughly by the traffic, it does not adhere to the ground, and gradually liquifies, so that at the end of four or five hours the streets may be cleared by the sweeping-machine, the caoutchouc rake passed over the foot-paths, and the mixture washed to the sewers by the addition of water. This cold mixture does no harm to paved roads, asphalt, and wood pavements; but salt should not be used on macadamized roads, which are disintegrated by the frequent artificial thaws thereby occasioned. This affords another reason for discontinuing macadamised roads in large towns, in France, which possess the great disadvantages of being very muddy in rainy weather, or during thaws, and of discharging quantities of sand into the sewers. The employment of salt would probably be very restricted in countries where the temperature often falls below 5°; but everywhere else it furnishes the best means of dealing with snow. It has been suggested that the coldness of the mixture is disagreeable to foot-passengers, destructive to boots, and bad for horses' feet; but the latter can be protected by greasing the inside of the hoof, and as the mixture should be removed directly it becomes liquid, the inconvenience, both to men and animals, is very short in duration, and very slight, compared with the advantages and economy of the system. The salt should be scattered in the proportion of about 1 dram per square foot for each four-tenths of an inch of thickness of snow fallen, or a larger amount if the temperature is low. Formerly each centimetre (0·4 inch) depth of snow falling in Paris necessitated an expenditure of over £2,400; whereas now the cost is only about £800, or a saving of two-thirds. Moreover the use of salt dispenses with sanding the streets, which, on the arrival of a thaw, produced quantities of mud in the streets, and deposit in the sewers. Further, if the cessation of interruptions of traffic by means of this process is taken into account, the indirect gain to the people of Paris must be reckoned by millions of francs. Several machines have been devised for the removal of snow, but none of them are as cheap as salt; and the Author gives a comparative estimate of the cost of melting snow by steam, and by salt, which shows that the method of steam would be much more expensive, besides entailing other disadvantages. The use of salt will probably not be confined to the clearing of streets in towns, but be extended to all paved roads, to tramways, and to the approaches to railway stations, and all large manufactories. Perhaps, even in France at any rate, salt might be used for dealing with snow-

drifts in railway cuttings, by spreading it in sufficient quantities and sweeping thin layers successively salted. On all paved roads over which there is considerable traffic, the use of only half the proportion of salt adopted in Paris would enable a track of 6½ to 10 feet in width to be dealt with, along which the snow would be prevented from being frozen to the ground, and thus rendering traffic almost impracticable. The small cost of the system, and the advantages to traffic, are sufficient reasons for an early and wide extension of the use of salt for removing snow.

L. V. H.

Galvanized Iron Pipes for Water-Supply.

(Gesundheits-Ingenieur, No. 16, Aug. 15, 1886, p. 526.)

At the 26th annual meeting of German gas- and waterworks engineers held at Eisenach on June 10th, Dr. Bunte presented the report of the committee appointed at the previous meeting to inquire into the suitability of galvanized iron for water-pipes. The report set forth the present position of this question, and contained the results of a series of experiments directly bearing upon the subject, from which it appeared that in the case of new pipes the water invariably takes up zinc; but that the same is in no way injurious to health. Special reference was made to similar experiments conducted in America, the results of which have been communicated to the society. It was unanimously resolved after discussion, that "The employment of galvanized wrought-iron pipes for water-supply occasions no injury to health." After further consideration, it was decided to commission the secretary to institute similar inquiries and experiments touching the use of lead pipes for water-supply, and to present a report to the next meeting.

G. R. R.

The Efficiency of a Pipe-System for furnishing Water to Fire-Engines.

By S. Bent Russell.

(Journal of the Association of Engineering Societies, 1886, p. 279.)

This Paper is a resumé of an extensive series of experiments carried out by the Author for the purpose of arriving at statistics on the problem of furnishing a sufficient quantity of water to supply a maximum number of fire-engines at any point of the city with the most economical and efficient planning of pipes consistent

with assured safety. The method of conducting the experiments, and calculating the efficiency of the pipes and jets is detailed, and the result set forth in fourteen Tables, which do not admit of condensation in any useful form.

The requirements of a system of water-distribution for domestic purposes differ from those of a system for fire-protection in that the former requires a capacity to furnish a small quantity of water to every point of the system at the same time, while the latter requires a capacity to furnish a large quantity of water at any one point of the system and in the shortest possible time. In ordinary cases a system of pipes designed for domestic purposes only would have a capacity unnecessarily large for fire-protection near the source of supply, and insufficient at the further extremities. For economical planning of a system of water-supply for purposes of fire-extinction the quantity of water required for any district depends to an extent on the rateable value; for the same protection that would be wanted in a first-class closely built business quarter is not requisite in a sparsely covered residential district. If 6,000 gallons per minute—a supply for about twenty engines—is allowed in the former case, the quantity might vary in outlying districts from 2,500 to 1,000. No pipe of less than 6 inches diameter is used in St. Louis for the supply of fire-plugs.

P. W. B.

Chemical Investigations at the Breslau Sewage-Irrigation Works.

By R. Klopsch.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xviii., 1886, p. 128.)

The sewage-water of Breslau, which annually amounts to about 11 or 12 millions of cubic metres, being at the rate of 115 litres per head per diem, is dealt with at the irrigation works at Oswitz. The composition of the sewage-water is as follows:—

	Per 100,000 parts.
Residue on evaporation . .	98·14 to 150·50 parts
Ash	57·70 „ 76·90 „
Loss on combustion . . .	40·40 „ 73·60 „
Nitrogen	6·55 „ 12·72 „
Sulphuric acid	4·25 „ 11·81 „
Chlorine	10·74 „ 15·17 „
Phosphoric acid	1·72 „ 2·95 „
Potash	4·72 „ 8·58 „
Soda	9·00 „ 12·38 „
Lime	4·42 „ 9·93 „

The subsoil water, after irrigation, has an average composition as follows.—

	Per 100,000 parts.
Residue on evaporation	56·15 parts.
Ash	46·14 „
Loss on combustion	10·01 „
Total nitrogen	3·04 „
Sulphuric acid	8·08 „
Chlorine	9·727 „
Phosphoric acid	trace
Potash	1·58 „
Soda	9·58 „
Lime	10·27 „
Ammonia	0·30 „

The nitrogen found in the sewage-water was present in organic compounds and as ammonia, but in the effluent it existed chiefly as ammonia and as nitrous and nitric acid, and only in small quantities in organic compounds.

The soil absorbed much potash but very little soda; it retained much of the nitrogen, but not to such an extent as to render it over-manured. Most of the nitrogen passed off with the effluent as nitrates and nitrites, or at any rate more than was taken up by plants. G. R. R.

Sewage-Purification at Ottensee.

(Gesundheits-Ingenieur, 1886, p. 496.)

Some experiments have been carried out by the firm of R. Müller and Co., Schöneback, with the process invented by Nahusen. The plan adopted is as follows. The soluble nitrogenous organic or inorganic constituents are precipitated in an insoluble form by the addition of salts of alumina, silicic acid and lime. For this purpose two pits, about 7 metres in depth and 1·5 metre in diameter, situated side by side, are employed. After the addition of the chemicals the water enters the first pit by means of an inlet-pipe, which is carried down almost to the bottom, and the sewage slowly rises to the top, whence the overflow passes by a similarly arranged pipe into the second tank. The solid precipitate falls to the bottom and is removed by a sludge pump. The sludge is then treated in a filter-press and is dried for sale as a manure. The works, when carried on continuously, are capable of dealing with a large volume of foul water. The precipitants are fully utilized; the water is entirely deprived of suspended matters, and loses, after passing through the second tank, from 30 to 40 per cent. of the nitrogen. Each cubic metre of sewage-water yields 2 kilograms of sludge, which it is hoped will have a value of from 5 to 6 marks per 100 kilograms. The annual cost of treatment is said to be at least 1 mark per head, without allowing for expenditure on works and plant. Assuming the volume of sewage at 40 cubic metres per head yearly, the expense per cubic metre would thus be 2·5 pfennige, and taking the value of the resultant manure at 60 pfennige per 100 kilograms, the total annual expense per head amounts to 52 pfennige (6·2*d.*). G. R. R.

Drainage of the St. Jürgensfeld.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 688.)

The St. Jürgensfeld is a tract of low-lying pasture-land, about twenty square miles in extent, situated between Bremen and Bremerhafen. It is traversed by the Wümme and the Hamme, two tributaries of the Weser; the level being above the lowest, but below the mean water-level of these streams. Dykes are constructed sufficiently high for protection against ordinary summer tides; but in autumn the sluices are opened and the whole district flooded, as the winter tides would otherwise break down the dykes, on which the houses are all built. There are no roads, all communication being by canal.

As it frequently happens that the level of the rivers does not fall sufficiently early in the season to allow of the district being drained off, and that great difficulty is also experienced in disposing of the water after heavy rains, the associated landowners have recently erected adequate pumping machinery, by which with the engines working day and night, the whole district (estimated to contain a volume of 50,000,000 tons of water) can be thoroughly drained in seven weeks.

The work is performed by three centrifugal pumps on horizontal shafts, driven by separate engines, and making from 75 to 85 revolutions per minute. The machinery is all below the highest flood-level, so that the walls of the building are constructed to provide against all irruption of water. The air-pumps (single-acting) are vertical, and the cylinders are fitted with Meyer's expansion-gear. There are three double boilers: the lower containing the flues for firing, and the upper being fitted with the circulating tubes. The delivery-pipes open under the lowest water-level, and are fitted with valves to prevent return of water. The greatest velocity of water in the pumps is 8·6 feet per second.

Subjoined are the leading dimensions of the engines, pumps, and boilers:—

Engines:—	Diameter of cylinders	23·64 and 13·79 inches respectively.
	Stroke	27·58 inches.
	Number of strokes	70 to 85 per minute.
Air-pumps:—	Diameter	15·36 inches.
	Stroke	13·79 „
Centrifugal pumps:—	Diameter over disks	78·8 inches.
	Width of „	26·79 „
	Vertical height of outer casing	12 feet 3·75 inches.
	Delivery-pipe	59 inches diameter, 18·94 square feet sectional area.
	Suction-pipe, at pump	41·76 inches diameter, 18·99 square feet sectional area.
	„ at lower end (egg-shaped)	49·25 × 33·49 inches, 19·52 square feet sectional area.

Steam-boilers:— .	Diameter of upper boiler	.	66·98 inches.
	Length „ „	.	122·14 „
	Diameter of lower „	.	66·98 „
	Length „ „	.	155·63 „
	Diameter of flues .	. .	24·82 „
	Heating-surface .	. .	932·16 square feet.
	Firegrate „	. . .	24·43 „
	Specified pressure .	. .	88·2 lbs. per square inch.

The total cost of the work was about £11,000, half of this sum being for machinery, and half for buildings and foundations.

P. W. B.

The Epidemic of Enteric Fever at Hamburg in 1885.

By Dr. M. Simmonds.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xviii., 1886, p. 537.)

In the course of the year 1885 Hamburg was visited by an outbreak of typhoid fever, which caused the cases of illness from this disease that for a long time past had fluctuated between ten and thirty-five per week to increase rapidly to an average of one hundred patients weekly, with a corresponding rise in the death-rate. The epidemic could in no wise be considered as a local manifestation of an outbreak extending over a large area of country, for in other towns similarly situated in the North German basin, as for example, Berlin, Hanover, Bremen, Lubeck, &c., no unusual number of cases of illness from this cause were recorded. The conditions as respects temperature, rainfall, and subsoil-water level were all favourable; neither could any introduction of the malady from elsewhere have taken place, seeing that typhoid has for many years past been endemic in the locality. The Author remarks that two other factors must, in the present state of the question, be studied with the utmost attention—the sewerage and the water-supply. As regards the former, there can be no hesitation in stating that the drains can have had nothing to do with the outbreak. Ever since the systematic sewering of the town was commenced, some fourteen years ago, the death-rate from typhoid fever has steadily decreased, and while in the eight years previous to the construction of the sewers, 48 deaths out of every 1,000 were assigned to enteric fever, the corresponding numbers in the succeeding years have been 38, 30, 22, 18, 12—a decrease which cannot fail to demonstrate the advantageous influence of the drainage. The evidence afforded by the annual death-rate per 10,000 inhabitants will serve to confirm these figures; thus in the three years ending 1873 the deaths attributed to enteric fever were 174; in the same period ending 1876, 143; ending 1879, 94; ending 1882, 83; and in the three years ending 1885 the deaths rose again to 93. The death-rate has been lowest in the well-drained parts of the town, and

highest in the undrained suburbs. Turning to the condition of the drinking water, the circumstances are less favourable; the works situated at Rothenburgsort, two kilometres above the town, derive their supply from the Elbe, the water of which is pumped into the reservoirs or direct into the mains, and, owing to the great increase in the consumption, the authorities scarcely discriminate between the water drawn from the reservoirs and that obtained direct from the river. In the spring of the year (and particularly was this so last year) the river-water takes a yellowish tinge, and throughout the year it is rich in deposits of all kinds, and the lower organisms found in the Elbe are present in abundance in the mains. The outfall of the sewage is situated a few kilometres lower down the river, and from float experiments conducted by Gill and Foelsch, it was proved that it was possible for the float placed at the mouth of the sewer to be driven backwards by the high water into close proximity with the intake of the waterworks, and pollution of the drinking water with the sewage becomes possible at high tides during the summer months when the river is low. The typhoid bacilli can exist in the water and multiply therein when the temperature exceeds 16° Centigrade, and in the supply cisterns placed beneath the roofs of the houses this temperature is often reached. It has not been possible as yet to definitely trace the outbreak to impure drinking water, but various reasons are given by the Author in support of this hypothesis. He suggests that the intake of the waterworks should be removed higher up the river, that careful filtration should be resorted to, and that the domestic cisterns should be abolished. For the time being, he urges that all water used for drinking and cooking purposes should be sterilized by previous boiling.

G. R. R.

Notes on the Healthfulness of Lands reclaimed from the Sea.

(Giornale del Genio Civile, April, 1886, p. 163.)

This question has been raised in connection with the reclamation of the Ostia and Maccarese marshes, and information has been collected upon the subject. In lands recently cultivated in the Venetian lagoons, it has been found that, even those of the most pervious character, when once freed from their saltness, derive no injury from the salt water which surrounds them, though divided into narrow strips by a network of sea canals. Some of the lands referred to have been raised above the highest tide-level, others, not so elevated, are protected by banks, sluices being provided for discharging the drainage water. These sluices have frequently been constructed of such sizes as to prevent fish passing through them, while allowing free passage for the water, but the consequence has been that they have retained decomposing matter which should have been allowed to pass out to sea, and the ditches

have in consequence become foul. Moreover the sluices have often been left shut from carelessness, and the water inside has become stagnant, causing malaria and fever. A commission appointed to inquire into the unhealthiness of the district, ascertained that it was due to the above causes. They ordered the fishing-industry to be abandoned, had sluices put up which could be opened and shut with ease, and which would give a clear water-way, and also provided for a circulation of sea-water by arranging that it should be allowed to enter by one set of sluices, and pass out at others. The result was that fever disappeared, and the cultivated lands, consisting of market gardens and vineyards, sustained no injury from the free admission of sea-water into the channels. After a time carelessness again prevailed, and with it the fever returned; another commission was appointed, and confirmed the decisions of the first with similar satisfactory results. While there is no doubt that agricultural and horticultural produce of the highest class may be raised upon reclaimed land, there is some uncertainty as to the length of time required before the effects of the salt entirely disappear. This appears to depend to some extent upon the soil. Where this is sandy, cultivation can be successfully carried on as soon as the salt water is excluded, but for clayey soils, some time must elapse before they become valuable. By sowing, in the first instance, suitable seeds, such as artichokes and beans, a fair yield may be obtained in most cases after a year or two.

It is a fact well understood in the Netherlands, that an extensive reclamation frequently causes temporary outbreaks of fever, but in the course of two or three years, as the ground dries up, these disappear, and the health of the district is permanently improved. Similar effects have been observed in Ferrara and in the valley of the Po.

W. H. T.

The Effect of River-Pollution on the Life of Fish.

By C. Aird, of Berlin.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xviii., 1886, p. 614.)

The policy of permitting the discharge of town sewage into public water-courses has long been a matter of controversy on the Continent, but the questions relating to the influence of this practice upon the fish in the rivers have not received sufficient attention. The Author points out that, although most of the native fresh-water fishes are raptorial in their habits, they differ greatly in their haunts, some remaining by preference in stagnant muddy water; others burying themselves wholly in the mud; while others again are capable of thriving only in bright, clear water. All fish need a supply of oxygen in order to exist, but the amount of oxygen present in different kinds of water varies greatly. Where

fish have been killed by discharges into streams, it will be found that death has been due either to poisoning by some specific toxic agent, or to suffocation. Ordinary town sewage, as commonly composed of domestic waste-water and rainfall, when discharged fresh day by day, cannot be regarded as a fish-poison, and especially not in those cases where no chemical system of purification is resorted to. Many kinds of fish feed greedily on the matters passing from the town sewers; and though they cannot exist in the sewers themselves, their death in the sewer would be due to suffocation from lack of oxygen, and not to poisoning. The Author instances the case of London, where, owing to the discharge of vast quantities of sewage into the Thames at Crossness and Barking, not only have the river-fish been destroyed, but even the living fish in the Dutch well-boats have become suffocated during their passage up the river to the Port of London. The amount of oxygen present in the water at various points from Teddington to Southend is given in tabular form.

Applying these observations to Berlin, and to the recent destruction of fish in the Spree, the Author shows that the chief evil has arisen in times of heavy rainfall, during thunderstorms, when the numerous storm-overflows have come into action, and in particular in the great storm of July 22nd in the present year, when from actual observation he found that the fish, which were killed in considerable numbers, had died of suffocation in consequence of the enormous pollution of the river, due to the escape of raw sewage into the Spree from the surcharged sewers.

G. R. R.

The New General Post-Office, Paris. By — GUADET.

(Mémoires de la Société des Ingénieurs-civils, 1886, p. 515.)

The Author points out that an ideal post-office would consist of a number of large halls on one level, but that his task at Paris in planning the new buildings was to superpose the various departments in order to economise space, and then to connect the different floors by a multiplicity of speedy and powerful lifts, so placed as to enable every branch of the service to be carried on without delay or interruption. The buildings may be considered to include two main divisions, the one accessible to the public, the other reserved for the use of the officials. The entrances to each are entirely distinct, and while the public department occupies the shortest front in the Rue du Louvre, the three longer sides of the block are set apart for the arrival and departure of the vans, and for the admission of the letter-carriers and officials. The total area of the site, which has roads on all sides, is 7,736 square metres (83,272 square feet), and the available space in the different floors is 28,046 square metres, equal to 3·62 square metres of floor-space per metre of surface covered. Nearly the whole of the ground

floor, with the exception of the space set apart for the use of the public, is employed for a series of courtyards for the arrival and departure of the post-office vans, for loading and unloading the same, and for the omnibuses in which the postmen are conveyed to and from their beats. The letter-carriers themselves act as sorters, and have to report themselves at the office for each delivery. The basement serves for the stables, heating-apparatus, steam-power, fuel, &c., and the front basement is set apart as a sorting-room for the printed matters. The first floor is the "distribution" department for sorting the incoming letters; the second floor is allotted to the making up and despatch of outgoing mails.

Though the enclosing walls are of masonry, the framework of the building is entirely of iron, and the external supports are so designed that the walls might be removed without injury to the stability of the structure.

The entrances and exits are all kept distinct, and have been so arranged that no interference with the stream of traffic is possible, as there is no turning round or crossing in any part. The letters from every part of Paris come to the chief office to be sorted and distributed, and the plan there followed differs in this respect from the London system, where, owing to the adoption of the postal districts, the work may be considered as being carried on in the offices of six or eight separate towns. A special department is allotted to what are called the "periodicals," *i.e.* the newspapers and literature of every description brought to the office in vehicles; and a covered hall at the rear of the public portion of the building has been designed for this service. The parcels are deposited by the porters on counterbalanced receptacles, which speedily lower them into the basement in the exact order of their delivery. Here, in a spacious well-lighted hall, they are handed over to a host of stampers, who at once transfer them to a series of baskets on wheels in which they are conveyed to the several departments, either for delivery in Paris, or for expedition to the provinces and to foreign parts.

Large spaces are reserved to serve as standing-places for the omnibuses which carry the postmen to and from the building. To supply these omnibuses there are stables in the basement for relays of forty horses, together with the requisite harness-rooms, storage space for forage, &c. The stables are reached by an inclined passage from the courtyard. The mail-bags as they arrive are raised to the first and second floors by lifts analogous to those used for the periodicals; but these hoists, rapid and powerful as they are in action, do not suffice for the lowering of the mails at the time of their departure. The printed matters and letters are constantly being received on the upper floors, as they come in at intervals throughout the day; but once the stamping and sorting has been accomplished, especially that for the night mails, nearly all of which leave at the same hour, there is a perfect avalanche of mail-bags to be provided for, in fact some

hundreds of heavy packages have to be sent down from the second floor to the courtyard in the course of a very few minutes. In the case of the hoists a distance has to be traversed of 25·80 metres (84·6 feet). To obtain the raising-power the Author bethought himself of the principle of the noria, with flat shelves in lieu of buckets, which must be constructed so as to revolve, but must always maintain their horizontal position in order to avoid the possibility of a fall in the case of bags accidentally left behind on them. The apparatus, moreover, must needs be intermittent in action, to allow time for loading and unloading. It must stop and start automatically, and must be provided at every opening with guards to prevent accident. All these conditions have been complied with in the contrivances in use at the new post-office. Four of them have been fixed, each one capable of carrying up a load of 200 kilograms every twenty-four seconds, say one hundred and fifty journeys per hour, equivalent to raising $600 \times 200 = 120{,}000$ kilograms of mails hourly. To provide for the lowering of the full bags from the second floor, a total distance of about 15 metres, the Author has introduced a system of spiral inclined planes, which allow the bags to slide steadily down by their own weight in about seven seconds. Four series of planes, wound two and two on different axes, discharge automatically at four circular openings, each of which is 2 metres in diameter; the working power of this simple contrivance is only limited by the rapidity with which the staff are able to cast in and take out the bags.

Particulars are given of the weight of metal used in the different parts of the building, the total lengths of piping of various kinds employed, the calculated weights of each kind of flooring, and of the metal work of the roofs.

In the case of the cast-iron supports, a maximum load of 8 kilograms per square millimetre has been worked up to, and for wrought-iron work 6 kilos per square millimetre (5·08 tons and 3·81 tons per square inch respectively). The article is illustrated with detail plans of each floor, together with a cross section and an elevation of the building.

G. R. R.

The Dulac Steam-Boiler. By — Maire.

(Bulletin de la Société Scientifique Industrielle de Marseille, 1886, p. 20.)

This is a sectional boiler, widely employed in the north of France and in the neighbourhood of Lyons. The "unit of evaporation," or one element, consists of three heaters (*bouilleurs*) and a boiler (*corps de chaudière*) in a vertical line; the heaters enveloped in the burning gases, and the boiler built into the upper part of the furnace. The boiler, as a whole, is succeeded by economizer-tubes (*réchauffeurs*). The heaters and economizer-tubes are 23½ inches in diameter, 11½ feet long; the boilers proper are 2 feet 7½ inches in diameter, 14¾ feet long. Both heaters and boilers are

of plate-iron, with cast-iron ends. They are all connected at each end to a vertical circulating pipe, water entering at one end, and a mixture of water and steam passing out at the other end of the heaters, which are inclined upwards. Thus a continuous circulation is maintained, in the course of which the steam is collected in the boiler, which, at normal level, is half-full of water. Steam is taken from the boiler at the back, or comparatively quiet, end, where the steam has shaken off any water that may have been lifting in mixture with it at the ascension end. Calcareous deposits are expected to settle at the lower ends of the vertical circulating pipes, whence they are blown out.

To complete the system of preliminary heating, the féed-water is passed through a number of 4-inch tubes in the flue, before it passes into the economizer. The furnace is made with two thick walls, about 32 inches thick, parallel to the heaters and boilers, and by thinner walls at the ends. The economizer is placed in a second chamber, which is so connected that the draught in the first place ascends from the fire-grate, through the heaters, and then descends between the economizer-tubes and the smaller 4-inch tubes, and finally passes away by a low-level flue.

Two or more elements may be grouped side by side, with a sufficient number of economizer-tubes to follow. The fire-grate is placed transversely to the heaters.

The Galloway boiler, also, is widely adopted in the same districts. The following are results of trials of the two kinds of boiler. The Dulac boiler consists of two elements, followed by five economizer-tubes and fifteen 4-inch tubes, at the works of Messrs. Bouvier Brothers, Vienna. The Galloway boiler is at work at the military mills, Lyons. In the Dulac boiler, the direct heating-surface for one element is 217 square feet; the volume of water of three heaters and one boiler is 145 cubic feet; the volume of each economizer-tube is 35 cubic feet.

Type of boiler	Galloway	Dulac.
Date of trial	Aug. 20, 1885	Jan. 5, 1886.
Duration of the trial	10 h. 0 m.	8 h. 45 m.
Coal used	Villebœuf, small.	Combrigol, large & small
Coal consumed per hour	141·24 lbs.	356 lbs.
" " " square foot of fire-grate	10·29 "	9·48 "
Ash and clinker	2·97 per cent.	19·6 per cent.
Pressure of steam during the trial, per square inch	79 lbs.	72 lbs.
Temperature of the feed-water	68° Fahr.	64° Fahr.
Water, as at 32° Fahr., evaporated per hour	1,307 lbs.	2,834 lbs.
" " " " per square foot of heating surface	16·33 "	35·43 "
" " " " per lb. of coal	9·25 "	7·96 "
" " " " " " combustible	9·53 "	9·92 "

D. K. C.

Test of the Kingsley Steam-Boiler.

(Journal of the Franklin Institute, October 1886, p. 316.)

The Kingsley boiler was tested at the Novelties Exhibition of the Franklin Institute, in November 1885, by a sub-committee of the judges. The shell of the boiler is flat-sided, with hemispherical top and bottom, approximately 3 feet 2 inches wide, 5¾ feet high, 13 feet long.[1] The sides and lower hemisphere are formed as a water-space, of an inverted horse-shoe form in section, connected at the top by a flat roof-plate. From the roof-plate there hang two hundred and seventy-nine simple water-tubes, about 2 inches in diameter outside, and about 2¾ feet long, except over the fire-grate, where they are only 15 inches long. The top, sides, bottom, and back, of the boiler are enveloped in brickwork. The fire-grate is internal, at one end, and the burnt gases pass through the boiler and between the water-tubes to the back, whence they return along the outside of the boiler to the front. The grate is 4½ feet long, 2 feet 8 inches wide, having 12 square feet of area. The water-heating surface is 592·03 square feet, and the steam-heating surface is 52·97 square feet, making together 645 square feet, or fifty-four times the grate-area. The chimney is of wrought-iron plates, 2 feet in diameter, 47 feet high above the grate.

Two trials were made, one for evaporative efficiency, one for capacity. Steam was got up, and the fire withdrawn. A second fire was lighted, and the test was held to commence when the boiler made steam. The leading results are given in the following Table:—

KINGSLEY BOILER.

No. of test	1	2
Date of test	Nov. 7, 1885	Nov. 7, 1885
Object of test	For efficiency	For capacity
Duration of test	9 h. 50 m.	10 h. 5 m.
Coal, per hour (Powelton bituminous steam-ship coal)	224·27 lbs.	296·06 lbs.
„ „ square foot of fire-grate	18·69 „	24·67 „
Ash	9 per cent.	10 per cent.
Average position of damper, open	0·83 inch.	Wide open
Temperature of the atmosphere	70°·9 Fahr.	73°·4 Fahr.
„ in the smoke-stack	227·1 „	281·0 „
Draught in the smoke-stack—inch of water	0·33 inch	0·66 inch
Working-pressure of steam per square inch	68·6 lbs.	69·4 lbs.
Temperature of feed-water	166°·8 Fahr.	164°·4 Fahr.
Water evaporated per hour	2,077 lbs.	2,570 lbs.
„ „ „ square foot of fire-grate	34·13 cub. feet	42·27 cub. feet
„ „ „ lb. of coal	9·26 lbs.	8·68 lbs.
„ „ „ „ „ from and at 212° Fahr.	9·97 „	9·37 „
„ „ „ „ combustible	10·06 „	9·59 „
„ „ „ „ „ from and at 212° Fahr.	10·83 „	10·35 „

[1] These dimensions are measured from the engraved illustration.—D. K. C.

The quality of the steam was tested from time to time during each trial. During the first trial it varied in condition from the holding of 5·9 per cent. of water to being superheated 40·3°; and during the second trial from 8·4 per cent. of water to 202·8° of superheat.

After the test, one short and one long tube was removed from the boiler and cut near their lower ends. The water poured from them was clear till near the bottom, when it became slightly muddy. In the bottom of the short tube, and for 3 inches up the sides, there was a thin scale about $\frac{1}{64}$ inch thick. The scale in the long tube was similar to this, with the addition of some fine granules. Otherwise the tubes, which had been at work for seven weeks, were perfectly clean.

D. K. C.

Experiments with a Boiler at the Emery-Works of Messrs. S. Oppenheim and Co. of Hannover.

(Zeitschrift des Verbandes der Dampfkessel- Ueberwachungs-Vereine, 1886, p. 121.)

These experiments were made with the object of determining what percentage of the heat developed from the fuel is utilized, and especially the proportion lost by conduction and radiation.

The boiler used was of the Lancashire type, with corrugated flues, constructed for a pressure of 5¼ atmospheres. The steam produced was used for working a steam-engine with tappet-valve gear, which drove a stone-crusher, a pair of grindstones, several riddles, &c., and the machine-tools in the workshop.

The fuel was carefully weighed out in equal quantities.

The feed-water was also weighed in a vessel holding about 500 litres (110·039 gallons), and the temperature observed at each weighing. The feed, the water-level, and the steam-pressure were kept as constant as possible.

The samples of fire-gases for analysis were taken from the smoke-flue immediately in front of the damper, where also the temperature was observed.

The temperature and degree of moisture of the air in the boiler-house were also determined.

The experiments lasted two days (the 16th and 17th of July, 1885), after a preliminary experiment on the 15th.

On the 15th and 16th the fuel was Westphalian coal, washed nut-coal from the "Germania" mine, while on the 17th it was beechwood charcoal.

The grate-area, which during the preliminary experiment was 1·97 square metre (21·205 square feet), was subsequently reduced to 1·34 square metre (14·424 square feet).

The other leading dimensions of the boiler were as follows:—

Heating-surface	71·82	square	metres.	773·08	square	feet.
Steam-space	9·56	cubic	,,	337·62	cubic	,,
Water ,, ...	16·50	,,	,,	582·73	,,	,,
Evaporative water-surface .	18·2	square	,,	195·90	square	,,
Sectional area above fire-bridge	0·46	,,	,,	4·95	,,	,,
,, ,, of internal flues	1·11	,,	,,	11·95	,,	,,

The following are the more important particulars and results of the three days' trials:—

—		Preliminary Trial. July 15.	Trials of July 16.	Trials of July 17.
Duration of trial	hours	9¼	10¼	10
Fuel		Coal	Coal	Charcoal
Consumption of fuel	lbs.	1295·20	1431·88	1638·01
Cinder	„	92·59	94·80	..
Ashes	„	52·91	25·35	12·125
Ashes and cinder in per cent.		11·2	8·38	0·74
Water evaporated	lbs.	12998·34	14382·26	14078·04
Mean temperature of feed-water	Cent.	19·6°	19·45°	19·7°
„ steam pressure	atmos.	4·9	4·9	4·9
„ temperature of fire gases in front of damper	Cent.	243·0°	235·3°	235·3°
„ temperature of air in boiler-house	„	26·4°	27·7°	26·8°
Ratio of grate-area to heating-surface		1 : 36·4	1 : 53·6	1 : 53·6
Water evaporated per lb. of fuel	lbs.	11·3	10·97	8·66
„ „ per square foot of heating surface per hour		1·816	1·771	1·822
Fuel burned per square foot of grate area per hour	lbs.	6·591	9·597	11·346
Heating power of fuel B.T.U. when dry (calorimetric determination)		..	13896·0	13123·8
Moisture in fuel used per cent.		..	1·4	1·45
Actual heating power B.T.U.		..	13734·0	12924·0
Distribution of heat per cent.:—				
Absorbed by water		..	83·6	76·0
Loss by cinders		..	0·9	..
„ carbonic oxide, &c.		..	0·3	4·9
„ higher temperature of fire-gases		..	10·6	10·9
„ conduction and radiation (as remainder)		..	4·6	8·2

G. R. B.

The New Weser Mills at Hameln.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 850.)

The mills recently erected for Messrs. Meyer and Company at Hameln, on the Weser, may be taken as a typical specimen of the most advanced practice in German mill construction and working. The mills comprise two sections. The first, or rye mill, capable of grinding and preparing 100 tons per diem, is situated on the right bank of the Weser, and was erected in 1878, but has quite recently been altered throughout to fit it for the cylinder-crushing process. The corn mill, which has a capacity of 175 tons per diem, is a fine block six stories high, forming three sides of a square, and situated on an islet in the Weser, across one arm of which a weir is constructed, by which head of water the turbines are driven.

The central block contains the mill-machinery; the northern wing containing the silos and screening-machinery, and the south wing the garner, bran-crushing machines, and stock rooms; the whole structure covering an area of about 2,200 square yards. The power for the whole of the machinery—about 600 HP.—is obtained from the six turbines; in addition to which there is a small turbine, with separate race, for driving the electric lighting machinery. The whole of the blocks of the building are isolated as far as possible by fireproof walls and rooms.

The grain is brought partly by land and partly by water, for which latter service the firm own fourteen vessels, including two steamers, one of 300 HP. These perform the service between the mills and Bremerhafen. On arrival at the mill, the grain is emptied into a shoot, by which it is conducted to an elevator within the building, which takes it to the garner on the upper floor of the south block. The grain arriving by land is delivered on to the belting under the silos (referred to later), and thence taken up by the elevator at the north end of the building.

The distribution of the grain to all parts of the different floors is effected by broad continuous travelling belting, the upper band carried on rollers with inclined axes, forming a grooved channel throughout; and the lower or return band (except in the basement belting) on horizontal axes, forming a level surface. For distributing the grain to any one of the eight silo bins (which together cover an area of 315 square yards, and have a capacity of 3,500 tons), a travelling roller-frame runs on wooden rails, to which it can be clamped at any point. One roller works in fixed bearings, the other in a radial frame. The upper strap being passed over both cylinders, and the radial arms being fixed in a nearly vertical position, a depression is formed to which the grain gravitates, and, by a side shovelling-arm attached to the frame, is shot out at the point required.

The grain, when stored in the bins, which extend from top to bottom of the building, is drawn out as required for manipulation by an opening at the apex of the inverted pyramidal base, by which it falls on to the concave channel of the travelling belt, which conveys it to the elevator for the purpose of successively undergoing the processes of screening, grinding, and dressing. It is the lower (and in this case also concave) band of this belting which similarly conveys the land-carried grain from the delivery-bin to the elevator at the other end of the building.

After passing through the cleaning- and screening-machines (consisting of winnowing cylinders and sorting drums, followed either by a rubbing-cylinder and brush-frame, or, where required, by washing instead of rubbing, in which latter case the grain is subjected to air at a high temperature to dry it again quickly) the grain is shot down a shaft adjoining the silos to the third floor, where the coarser grain is treated, the machinery here comprising two Millot's and nine Haggenmacher's machines, and eighteen sorting-cylinders (some in pairs) 16 feet 5 inches long, and 35·5

to 39·4 inches diameter. The second and fourth floors contain machinery for dressing and sorting the flour of different qualities after grinding, the first floor being devoted partly to offices and stores, and partly to finishing off the finest meal.

The grinding is all done on the ground floor with case-hardened iron cylinders. These are arranged in five rows. The first contains fifteen sets of fluted cylinders (two in each set) 8·67 inches in diameter, and 25·6 inches long, for coarse grinding; the second eleven sets, with finer fluting, of the same diameter, and 18·7 inches long; and the third eight sets, of smooth unfluted cylinders, for the next degree of fineness. The fourth row comprises nine sets, each of three cylinders, two of these being 8·67, and one—the axis of which is placed a little to the side—11·43 inches diameter. The fifth row consists of ten sets, each of four porcelain cylinders, for mealing the finest flour. These make together a total of forty-five sets of cylinders, and the grain thus manipulated is conveyed by an endless screw in a trough under the gangway to the elevator, to be passed on to the other floors for the further dressing-processes.

The Author gives plans and sections of all parts of the structure, with illustrations, and full description of the machinery employed.

P. W. B.

Notes on a Boiler-Explosion at Solre-le-Château (Nord).

(Annales des Mines, vol. ix., 1886, p. 364.)

The boiler in question, which exploded on the 7th of October, 1885, at the spinning-mills of Messrs. Pellot and Co., was of the ordinary tubulous type, with two water-tubes and three super-heating-tubes, having a total capacity of 25·86 cubic metres (913 cubic feet). It was of considerable age, but had been repaired and tested to 6 kilograms per square centimetre (85 lbs. per square inch) on the 27th of February, 1884. Besides the ordinary fittings, one of Naudin's self-registering gauges, giving a continuous record of the pressure on an endless roll of paper, was fixed in the manager's office near the boiler-house.

On the day before the explosion the boiler, which had been standing idle for three days, was thoroughly examined inside and out, and at 7 P.M., when the fire was lit, was in perfect order, together with all its mountings. As the chimney was cold, and the flues had been sluiced out with a jet of water, the draught was very bad, and considerable difficulty was experienced in keeping steam; in fact, between 7 A.M. and 12·30 P.M., the time of the explosion, the engine had come to a standstill five times for want of steam. The idea unluckily occurred to the fireman (probably about 10 A.M.) to improve matters by partially shutting off the feed, and there is no doubt that he unwittingly closed the feed valve altogether. As the water in the boiler diminished, the alternate stoppages of the engine and raising the steam to working

pressure occurred at more frequent intervals, until, the water in one of the tubes becoming completely exhausted, the plates became red-hot, and ripped open for a length of 1·80 metre (5 feet 11 inches). As the boiler was almost entirely empty, it was scarcely disturbed on its seat, and the damage, except to the front and back wall of the setting, was insignificant. The fireman, however, who was in front of the boiler, was fatally scalded.

It is evident that the fireman had either paid no attention to the gauge-glass, or had been misled by the condensation of steam in the tube, which may have formed a column of water balanced by the steam-pressure. In fact the manager, who passed a few minutes before the accident, reported that water was visible in the glass, but with considerable oscillation; and water was afterwards found in the copper tube of the water-gauge, which had been doubled sharp across by the explosion.

The theory usually received in cases of explosion arising from shortness of water is that the water injected on to the red-hot plates is suddenly flashed into a considerable volume of steam at high pressure; but in this case the recording pressure-gauge shows conclusively that the pressure at the moment of explosion did not exceed 5 kilograms per square centimetre (71 lbs. per square inch), while the feed, as above noted, was entirely shut off. There can, therefore, be little doubt that the explosion actually occurred in consequence of the diminished tensile strength of the plates when heated to redness, and their consequent inability to sustain even the ordinary working pressure; and that at this pressure even the employment of special safety-valves (such as the Barbe valve), permitting the rapid discharge of large volumes of steam would have been no safeguard.

The Paper is illustrated by an engraving of the diagram taken by the recording pressure-gauge.

W. S. H.

Corrosive Action of Saccharine Solutions on Steam-Boilers.

By D. Klein and A. Berg.

(Bulletin de la Société Scientifique Industrielle de Marseille, 1886, p. 7.)

In sugar-works, refineries, glucose-manufactories, where syrups are evaporated in vacuo, in boilers heated by steam in coils, and the condensed waters are returned to the boiler, it frequently happens when the coils are not tight that sugar is drawn in and lodged in the boiler. Can the syrup thus introduced corrode the plates? The Authors instituted a series of experiments to determine the action of sugar and other like substances—malt, gum, dextrine, glucose, glycerine—in solution in water, in known proportions, on prisms of plate-iron. The solutions were heated to from 240° to 300° Fahrenheit with these prisms, which were pre-

viously weighed. The quantity of iron dissolved was determined in two ways—by analysis of the liquor, and by ascertaining the loss of weight of the prisms. For the sake of comparison, a prism was heated in a sealed tube containing distilled water.

The tubes, containing each 1·83 cubic inch of water, were heated for several consecutive days during six hours a day. With distilled water, only sesquioxide of iron in suspension was obtained, part of which adhered to the prism and protected the metal. There was no solution of the iron. The prisms of iron weighed 205·67 grains average. In the second experiment, the first cube contained only distilled water; the second, third, fourth, and fifth tubes held in solution respectively 1, 2, 3, and 4 grams, or 15·43, 30·86, 46·29, and 61·72 grains of sugar. The losses of weight of the prisms were respectively 0·093, 0·262, 0·509, 0·802, and 0·648 grain. The dissolved iron was almost entirely in the state of the formula $Fe_2 O_3$ in solution. The tubes having been hermetically sealed during the test, it was found when they were opened that a partial vacuum had been produced in the first and second tubes; atmospheric pressure remained in the third; and in the fourth and fifth there was an excess of pressure, with a lively discharge of hydrogen.

From these results, it appears that in the attack on the iron in the first tube, due only to the air present in the tube, the sugar produced a solution, acting like organic acid matter, like a feeble acid such as citric acid. The proportion of iron dissolved varied from one-eighth to one-fifth of the weight of the sugar; it increased with the proportion of sugar dissolved.

The Authors extended their observations to the action of sugar on other metals, and other like substances on iron, under pressure. They conclude that certain neutral substances, when heated under pressure with steam, are transformed into acid compounds, which corrode iron, and that their action is like that of weak organic acids. Iron is attacked by gum arabic and dextrine under the same conditions with sugar, but much less actively; and the action is probably due to impurities in those substances.

In this connection, an observation of Mr. Klein's is quoted, to the effect that when sugar is heated in the presence of water under pressure the syrup becomes acid, and that the acidity is less at high temperatures than at 212° Fahrenheit.

D. K. C.

The Giroud Pressure-Regulator, or Reducing-Valve.

By Messrs. Rich-Berger, and Lévy.

(Bulletin de la Société Industrielle Mulhouse, August–September, 1886, p. 301–303.)

The Giroud pressure-regulator, described by Mr. Rich-Berger, consists of two chambers separated by a conoidal valve opening downwards. The stem of the valve is produced upwards and downwards, and terminates in a gun-metal piston above and one

below, each of which slides with a minimum of friction in a gun-metal cylinder. The upper piston is larger in diameter than the lower piston, but it is equal in diameter to the valve. The upper chamber receives steam from the boiler, and the steam passes from the lower chamber at reduced pressure.

By their own weight the pistons fall, the valve opens wide, and steam may be freely admitted into both chambers. But, under steam-pressure, the excess of pressure on the upper piston, which is the larger in diameter, causes the valve to remount; so reducing the opening of the valve, and diminishing the pressure in the lower chamber, until the weight of the pistons balances the excess pressure on the upper piston.

By the addition of weights on a scale suspended from the lower valve, the pressure of the steam passed through may be augmented at will. For a given pressure, the weight ought to be so much greater, the greater the difference of the areas of the pistons. The pistons are not packed, but are made practically steam-tight by a number of grooves turned in the circumference.

The double-piston apparatus above described is suitable for steam-pipes of large diameter for high pressures, and when the pressure outwards is to be rapidly and widely varied. But, in most cases, a uniform pressure is required, and a single-piston regulator suffices, loaded, when required, above the piston. The apparatus is available for steam, gas, or liquids.

Mr. Lévy gives the results of several experimental tests of the action of the Giroud regulator, of which the first may be noticed. Hourly observations were taken for a period of eleven hours, of the pressure in the boiler, the pressure at the entrance to the regulator, the pressure leaving it, and the number of boilers at work. It appears that whilst the number of boilers at work varied from one to four, and the total pressure in the boilers from $3\frac{1}{4}$ to $2\frac{1}{2}$ atmospheres, and that the pressure at the entrance to the regulator varied from $2\frac{10}{20}$ to $1\frac{10}{20}$ atmospheres, the pressure beyond the regulator was constant at $\frac{17}{20}$ atmosphere.

D. K. C.

Four Horse-power Steam-Engine.

(Portefeuille économique des Machines, 1886, col. 113.)

This engine, constructed by Messrs. Salomon Frères et Teuting, is composed of a horizontal cylinder, in which moves one long piston in place of two single-action pistons. This organ is formed of two terminal disks, each provided with three jointed segments of cast-iron. The disks are united by a piece cast along with them in which are formed the inlet and exhaust channels. A cam keyed to the crank-shaft makes the piston oscillate during its backward and forward movement so as to present the port of the slide-valve-forming piston alternately before the inlet- and exhaust-orifice.

The length of the former allows of admission during half the stroke, that of the latter of exhaust during the entire stroke. The axis of the shaft bisects the length of the cylinder at right angles. The outer end of the connecting-rod is strapped to one of the terminal disks of the piston. A Buss governor controls a valve placed in the steam in-let tube. Oil is applied at the middle of the cylinder, the unconsumed portion gathering in a hollow chamber beneath. The engline requires no piston-glands. Its normal speed is 180 revolutions per minute.

A. B.

Lifting-Machines on the Borde System. By G. L. Pesce.

(Le Génie Civil, vol. ix., p. 257, 1 plate and 3 woodcuts.)

The combination of power, rapidity, and economy in plant for the erection of works appears to have hitherto been best realized in the lifting-machines first designed by Borde in 1857, for the construction of some large houses along the Joliette quay at Marseilles, and improved in 1881 by Mr. Bonnet, and by Mr. G. Averly in 1884. Illustrations of these steam cranes, with hinged and balanced jibs, accompany the article. The machines erected at Marseilles could lift about 190 tons of materials per day to a height of 50 feet. A design by Mr. Bonnet, in 1881, of a machine for the rapid erection of the Paris Post-Office was identical with one type of Borde's, in having a staging and engine mounted on a carriage running on rails parallel to the building, with a balanced jib oscillating transversely on a central pivot, being guided at one end, and having the load hanging from the other; but the hauling was effected by chains instead of cables. Its height was 44¼ feet. A larger machine was designed by Mr. Bonnet, in 1882, for erecting the nave of Sacré-Cœur Church at Montmartre, of which the arches rise 88½ feet above the floor. The pitch-pine staging was 82 feet high from rail-level to the central axis of the jib. The jib consisted of two parallel trellis girders, 36 feet long, 16 inches high at the axis in the centre and 10 inches at the ends, braced with tie-rods above, and provided with pulleys at each end. A counterpoise weight attached to the centre of the jib, at a little distance underneath the axis, brought the centre of gravity of the jib below its centre of oscillation, causing its working to be more regular. In 1881, Messrs. Satre and Averly, of Lyons, constructed a machine, after the model of the Borde machines at Marseilles, which could lift to a height of 100 feet, and eventually, by raising the staging, to a height of 130 feet. Mr. G. Averly built a similar machine in 1884 for the erection of the viaduct of Dombief on the railway from Champagnole to St. Claude. This crane ran along a temporary bridge raised about 33 feet above the bottom of the ravine; it could raise a load of 29 cwt., and lay stones at a height of 100 feet above the

bridge; and it furnished the materials for five piers, on each of which four or five masons were at work. The jib was a trellis box girder, with the upper flange parabolic, and the lower flange straight; its length was 72 feet, giving a working arm of about half that length, and its pivot, on the top of the staging, was 69 feet above the bridge. The jib was worked by hand, its lifting end being raised or lowered by means of a single-purchase crab or a brake, respectively, acting on the tail-end. The lifting of the load was effected, at the rate of 10 inches per second, by a double-purchase crab worked by an engine of about 8 HP., which also served to move the whole machine along rails laid to a gauge of 11½ feet. Many years elapsed before builders thought of profiting by Borde's invention, and even now this type of crane has not been extensively adopted, in spite of the advantages which it offers. L. V. H.

On the Determination of the Weight of Anvils for Vertical Hammers. By Professor FRIEDRICH KICK.

(Technische Blätter, 1886, p. 24.)

The question as to the weight which an anvil should have is one which may often occur in practice. The difference between that which is called static pressure and blows or impact lies in the time occupied by their action. The weight of the hammer, and the distance through which it falls determine the total energy expended; but the force of the blow, with a given expenditure of energy depends on the compression produced in the piece struck; the less the compression the greater the force of the blow.

Some experiments were made by the Author for the purpose of comparing the effect produced by an ordinary hammer striking on a firmly-bedded anvil and a so-called ballistic hammer, where both hammer and anvil are suspended pendulum-fashion, so that the anvil is free to move. It has been proved for various materials, that within tolerably wide limits, the work expended on changing the form of a piece resulting from a blow, depends only on the product of the weight of the hammer by the height of fall, the limits for the latter being ½ to 3 metres (1 foot 7·69 inches to 9 feet 10·14 inches). The test-pieces used by the Author consisted of small cylinders of copper cut from the same bar and of the same original dimensions. One series of test-pieces was subjected to blows of a certain energy from an ordinary hammer, while on a second series the same energy was exerted by a ballistic hammer. The weight of the anvil to that of the hammer for the latter was in the ratio nearly of 2 to 1. The length and diameter of the test-pieces were respectively about 16·9 and 12·5 millimetres (0·66 and 0·49 inch), and the weight about 18·4 grams (0·64 oz.). The results showed that a greater alteration of form was produced

by the ordinary than by the ballistic hammer; in the case of the latter the energy transferred to the swinging anvil could be easily ascertained, and was found to be about 30 per cent. of the energy exerted by the hammer. Further experiments were made with the same apparatus to determine the energy of the blow required with the ordinary and ballistic hammer respectively to produce the same effect on similar test-pieces, the quantities were found to be in the ratio 7 : 9. Another series of experiments was undertaken with a ballistic hammer, in which the ratio of the weight of the anvil to that of the hammer was as 4 : 1; with this proportion the efficiency of the ballistic hammer was found to be as great as that of one with a firmly bedded anvil having twenty times the weight of the hammer. In practice, the weight of the anvil should be, for forging iron eight times, and for forging steel twelve times—at least—the weight of the hammer.

Test-pieces of as nearly as possible the same quality and dimensions as those previously used were subjected to a steady pressure in Professor Gollner's testing-machine, and the work required to produce a certain compression compared with the energy necessary to cause the same by means of a blow. The ratio of the latter to the former proved to be about 1·5; but this value varies according to circumstances, being greater for very hard substances and for repeated blows.

At least 20 per cent. of this excess of energy is transferred to the anvil, and the remainder lost in vibrations of the latter and of the hammer, or in heating the work.

G. R. B.

Arns's variable-power Pneumatic Hammer. By R. M. Daelen.

(Stahl und Eisen, 1886, p. 364.)

This hammer, which was exhibited at Antwerp in 1885, is built like a small steam-hammer, with a single standard and overhanging cylinder. The cylinder, open at both ends, has a packed piston in it, which is moved by a crank and connecting-rod, receiving motion from the driving-shaft above, and a tup at the bottom, which is not attached to the piston, but separated from it by a small space containing air. A hole bored through the cylinder forms a communication between the interior and the external air, which can be opened or closed by means of a cock. When the air-way is closed, the piston in rising distends the enclosed air, and the tup is lifted by atmospheric pressure, while in the return stroke the air is compressed and increases the blow of the tup against the anvil, the tup following the piston with extreme regularity by the alternate expansion and compression of the enclosed air. If the air-way of the cylinder is completely opened, the motion of the piston will only drive the air in and out above the tup, so that the latter will not move; and similarly, if

the passage be more or less throttled, the lift and force of the blow may be varied within considerable limits, but the blows will succeed each other exactly at the same intervals as the strokes of the piston. This allows the hammer to be used under very great variations of speed, and it is particularly useful when a very rapid succession of light blows is required in finishing forgings. This has not been hitherto attainable in the same degree, as in ordinary forging-machines the action is chiefly dependent upon the speed of the transmission.

The strength of the blow with this hammer is stated to be from two and a half to three times that of a self-acting steam-hammer of the same weight of tup. From the ease with which it may be regulated it is specially adapted for finishing work upon the tires of railway wheels; and a large one is now being constructed for the repairing shops of one of the German railways.

H. B.

Trials of Jonval Turbines at Göggingen.

By M. Schröter.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, pp. 781, 806.)

The two Jonval turbines, the performances of which are the subject of this communication, having been erected in the summer of 1884 by the Maschinenfabrik Augsburg for the spinning and cotton mills at Göggingen, near Augsburg, the Author was requested, as the professional adviser of the directors, to carry out experiments to test the efficiency of the machines. The conditions of testing imposed were to determine the efficiency:—

(1.) With turbines in full work and at different velocities.
(2.) With turbines in full work, with 1 foot increased head of water.
(3.) With three, five, or six sectors respectively shut off, and at different velocities as before.

The volume of water at the normal level is 25,428 cubic feet per minute, head of water 13·45 feet, and combined power of the two turbines = 656 HP. The regulating channel and turbine chamber are in concrete. The mean radius of turbine = 8 feet ½ inch; width on rim, 17·73 inches; normal revolutions per minute = 46; number of outer vanes = 36; ditto inner vanes = 38.

A very powerful brake arrangement was introduced to regulate the speed and measure the power, and has proved very effective. The brake acts on the upper end of the cylinder, and the lever, 20·46 feet in length, is a timber beam passing through an opening in the wall of the building (with a play of only 4 inches); at the outer end is fixed a chain, passing over a pulley and carrying a scale loaded with whatever weight is desired. By this arrangement all irregularity in working can be eliminated at a steady speed of 30 revolutions per minute.

With these data, the first step in arranging the trials was to establish the constants of work with regard to the action of the brake, where the effective work in HP., N =

$$\frac{20 \cdot 46 \times 3 \cdot 1416}{30 \times 75 \times 3 \cdot 281} G \cdot n = 0 \cdot 0086764\, G \cdot n. \quad . \quad . \quad (1)$$

(G = total strain on chain = load on brake-lever, and n = number of revolutions per minute). The moment of friction of the pivot is expressed by the formula—

$$M = \frac{4}{\pi} u\, G \times \rho = 0 \cdot 0084\, G \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where radius of pivot $\rho = 0 \cdot 361$, and coefficient of friction $u =$ 0·018.

The flow of water was measured with the greatest care, the apparatus (from the Royal Technical High School at Munich) having previously been used to test the current-meters by Elliott Brothers, Ertel and Son, and Löhner. The results of these tests are embodied in the Tables of results, and may be summarised as under (v being velocity of water in feet per second, and n the number of revolutions of the current-meter per second).

1. Elliott's meter:—

$$v = 1 \cdot 036\, n - 0 \cdot 0229.$$

Mean slip = 0·0068.

32 trials, velocity varying from 0·82 to 7·5 feet per second.

2. Ertel's meter, small wheel (4 inches diameter):—

(*a*) $v = 0 \cdot 05505 + 7 \cdot 90474\, n$, where $n > 0 \cdot 1$ or $v > 0 \cdot 82$ feet.

Mean slip = 0·007.

30 trials, velocity from 0·49 to 8·82 feet per second.

(*b*) $v = 0 \cdot 269 + 5 \cdot 840\, n$, where

$n = 0 \cdot 04$ to $0 \cdot 1$, and $v = 0 \cdot 49$ to $0 \cdot 82$.

Mean slip = 0·0085.

3. Ertel's meter, large wheel (12 inches diameter):—

$v = 0 \cdot 01036 + 10 \cdot 92484\, n$, where

$n > 0 \cdot 03$ or $v > 0 \cdot 32$.

Mean slip = 0·0077.

29 trials, velocity from 0·29 to 8·69 feet per second.

4. Löhner's meter:—

$v = 0 \cdot 098607 + 0 \cdot 09521\, n$, where

$n > 0 \cdot 1$ or $v > 0 \cdot 82$ feet.

Mean slip = 0·014.

29 trials, velocity from 0·36 to 8·76 feet per second.

For values of $n < 1$ or $v < 0 \cdot 82$ this gauge is not available.

The results of the trials are summarised in the subjoined Table.

Column 1 shows the number of trial.

Column 2 shows the duration of each trial in minutes.

Column 3 shows the mean quantity of water in gallons per minute. This, after being accurately gauged on the basis of the comparative results stated above, was checked by calculation, with results varying from 0·35 to 1·12 per cent. only.

Column 4 shows the average number of revolutions of turbine per minute.

Column 5 shows the total load in lbs. on brake-lever.

Column 6 shows the gross work in HP. of each turbine.

Column 7 shows the total effective work of each turbine.

Column 8 shows the ratio of effective power to gross work. This at normal speed, and with turbines in full action, attains to a maximum of 83·2 per cent., and a mean of 82 per cent., a result higher than specified (81 per cent.), and showing as full a proportion of power as has yet been attained.

1	2	3	4	5	6	7	8	9
No. of Trial.	Duration in Minutes.	Flow of Water in Gallons per Minute.	Average Number of Revolutions per Minute.	Total Load on Brake Lever.	Gross Work.	Effective Work.	Ratio of Effective to Gross Work.	Condition of Trial.
				Lbs.	HP.	HP.	Per cent.	
1	52	78,889	45·52	1,519	328·5	273·2	83·2	Turbine in full action.
2	52	80,406	44·92	1,519	333·0	269·6	81·0	" "
3	50	80,265	39·34	1,740	334·7	270·4	80·8	" "
4	46	80,278	51·76	1,320	336·5	269·8	80·1	" "
5	54	86,740	45·40	1,658	384·5	297·2	77·3	" " increased head of water.
6	45	59,855	45·29	1,112	250·0	198·9	79·5	3 sectors closed.
7	50	61,042	40·42	1,250	254·7	199·6	78·4	3 " "
8	48	48,613	44·35	867	202·7	151·9	74·9	5 " "
9	55	41,848	45·63	735	176·5	132·5	75·1	6 " "
10	54	41,258	40·28	819	172·3	130·3	75·6	6 " "
11	40	..	..	2,739	..	..	..	Brake full on.

P. W. B.

Combustion in the Gas-Engine. By R. Schöttler, Brunswick.

(Zeitschrift des Vereines deutscher Ingenieure, vol. xxx., 1886, p. 209.)

The manner in which the combustion of gases takes place in the gas-engine, the manner in which the charge is first formed and then ignited, has been in recent years the subject of considerable discussion and investigation. The various opinions proposed with

their proofs are discussed in this Paper. When a mixture of gas and air is exploded, it is always found that the pressure produced falls far short of that which should be produced if all the heat present were evolved instantaneously. This fact has been known since the publication of Bunsen's experiments. To understand the conditions of economy in gas-engines, it was early recognized that investigations of the properties of explosives were necessary.

In his introduction to Hirn's work, Grasshof says:—"In the Lenoir engine the cylinder in all cases rapidly conducts away the heat, and a moderately high piston-speed is necessary to secure economy. There will be, for every proportion of gaseous mixture, a fixed rate of piston-speed and temperature of cylinder, which will give the best result, and which can only be proved experimentally." Meidinger, reporting upon his experiments on a ½ HP. Otto and Langen engine, states that the principal cause of its economy over Lenoir's is its superior piston-speed. Reuleaux also energetically advocates the favourable influence of the greatest piston-speed.

In the Otto compression-engine the diagram shows that the expansion-line falls much more slowly than in the older gas-engines, even slower than the adiabatic line. But as heat is rapidly flowing through the sides of the cylinder, heat must be added during expansion to keep up the line; this is due to the continued burning of the charge after the explosion or the "nachbrennen." To discover whether this "nachbrennen" is peculiar to the Otto engine, or is common to all compression-engines with explosion, is the Author's object. In Otto's patent of 1876, No. 2081, it is stated that it may be produced without previous compression, and that the condition of its production is a certain stratified arrangement of charge, the gases in the cylinder being arranged in orderly succession, inert gas next the piston and explosive or inflammable gases next the igniting-flame. This is also true of his compression-engine. This Otto theory of "slow combustion" and "stratified layers," Slaby followed in a lecture in February 1878. His statement agreed entirely with Otto's, and may be summed up shortly. "In consequence of this arrangement of gases, the explosion of the entire charge cannot occur. But the flame will propagate itself only step by step from stratum to stratum, and cause the gradual expansion which gives useful work to the piston." Later on Redner said, with reference to the Otto compression-engine, "The ignition follows at the dead point, and the pressure quickly rises to 9 or 10 atmospheres; here there exists, no doubt, an explosion, but that it only exists in the immediate vicinity of the bottom of the cylinder, is proved by the nature of the expansion-line which follows it. If the explosion extended through the entire contents of the cylinder, the expansion-curve would, like the Lenoir diagram, fall very quickly. The gradual and gentle slope strongly urges the assumption that combustion continues from layer to layer during the whole stroke." Hormann objected to Slaby's view in the discussion of the

lecture, and said that "In the Lenoir engine the slow movement of the piston allows considerable cooling, and the expansion-line after explosion falls quickly. In the Otto engine the rapid movement of the piston gives less time for cooling, and the curve appears to fall more gradually." To this Slaby replied that he laid no great stress upon the stratification theory, and that one must wait for accurate measurements before deciding. In a second lecture, delivered the 3rd of March, 1879, Slaby adhered to the stratification theory as explaining the slow-falling curve. In the discussion Wedding proposed Bunsen's law of dissociation as an explanation, and pointed out that combustion could not possibly be completed at the maximum temperature of the explosion.

This view was powerfully maintained by Mr. Dugald Clerk, in a Paper read before the Institution of Civil Engineers on the 4th of April, 1882. Part of the Paper and discussion is quoted *in extenso* by the Author; he also mentions Clerk's experiment with one of his engines, where the charge was sampled next the piston and found to be explosive. Slaby himself describes the effect of dissociation later on, and states that it doubtless has some effect both in Otto and Lenoir engines. But he says the Otto engines show more heat kept back than dissociation could account for, and that this excess is due to stratification. He states that from Tresca's experiments on a Lenoir engine, 65 per cent. of the heat was evolved by explosion, leaving 35 per cent. to be evolved during expansion, while his own experiments on a 4-HP. Otto engine show 56 per cent. to be evolved by explosion, and 44 per cent. during expansion. In support of Slaby's statements the Author was shown experiments at the Deutz gas-engine factory. A 4-HP. Otto engine was fitted with an additional igniting-valve, placed on the side of the engine at the end of the compression-space next to the piston; when ignited with the usual end-valve, the usual diagram and the full power of the engine was obtained, but when the side-valve was used, the effective power fell to one-half, and the diagram showed that the ignition was much slower, the explosion-line inclining far forward into the stroke. No doubt this experiment speaks in favour of the Otto theory, and by those who are already convinced of its correctness it will be considered as complete proof. A third explanation has been put forward by Dr. Aimé Witz, which appears to be quite unprejudiced, and which quite contradicts the two first theories.

In the substantial influence of dissociation, the Author has never been able to believe, because, if true, the expansion-line should be isothermal till combustion was complete, which is not the case. Mallard and Le Chatelier have proved that dissociation does not act at the temperature common in gas-engines, and the figures of St. Clair Deville quoted by Clerk are for quantities so small as not to affect the observation. As the highest temperatures in gas-engines seldom exceed 1,500° C. (2,732° F.), dissociation cannot affect the question. The experiments of the French scientists once

and for all dispose of the dissociation theory. Likewise in view of their work the Otto theory has never from the beginning had much ground. The entering jet of air and gas moves at forty times the velocity of the piston, and therefore must overtake it and complete mixture occur; the conditions are most unfavourable for stratification, and favourable for mixing. The proportions would require complete alteration to give any chance of stratifying. The Deutz firm have presented the Technical High School of Hanover with a model which proves that stratification is possible under certain conditions. A piston moves in a brass cylinder by means of a crank, and a glass prolongation is fitted to it to represent the space at the end of the Otto-engine cylinder. It is provided with a cock through which the smoke of a cigarette can be sucked in. Open the cock while the piston stands at the end of its stroke and turn the crank quickly, a smoke-jet enters the cylinder, and it is observed that it does not reach the piston, but remains at the back, leaving a clear space or air-cushion between it and the piston. Stratification is therefore possible, but it does not occur in the gas-engine, because the cylinder is not long enough. The Author has made experiments with a model of Messrs. Körting Brothers' construction, which copied exactly the proportions of the Otto engine, and always found complete mixture of the whole contents of the cylinder, and obliteration of any trace of stratification.

Other experiments, however, prove that, whether stratification does or does not exist in the Otto engine, it has nothing to do with the slow falling of the expansion-curve. An engine made at the Mannheim gas-engine factory was arranged to be ignited in six different positions in the combustion-space, and in all cases the diagrams were practically identical, and in all of them the expansion line fell slowly. Similar results were obtained with an engine of Körting's. It was found that the mixture in the admission-port was always somewhat richer than that in the cylinder, but no stratification, in the Otto sense, was ever discovered.

The question therefore remains to be answered; why did the expansion-lines of the older engines fall more quickly than those of the newer ones? Witz has fully answered this question. He has established the fact that the influence of the walls determines the shape of the expansion-curve.

Witz sums up his conclusions as follows:—

"The influence of the walls is the great ruler of all explosive phenomena. It suffices either to retard or accelerate combustion, or to produce a slow and gradual combustion; it is unnecessary to fall back upon dissociation to explain slow combustion. As a matter of fact, slow combustion is obtained at temperatures so low as 1,400°, where dissociation is impossible. . . . These researches alternately invalidate and confirm the theory which Clerk warmly advocated at the Institution of Civil Engineers. With the English engineer, we are of opinion that slow combustion should not be sought after intentionally; this retardation is an imperfection. Otto is wrong to do so. Unluckily it cannot be completely avoided.

Why not? Because, says Clerk, the heat is only gradually developed by explosion of the gases, proportionally to the combination of the dissociated parts: because, say I, the influence of the walls can only be diminished, but not completely suppressed. I find myself in accord with Clerk, when he maintains that the success of Otto's engine is due to compression, and not to the great dilution of the explosive mixture in the exhaust gases of a preceding combustion."

The Author is of opinion that Witz's experiments were carefully carried out, and that his conclusions are correct; also that the combustion in the newer engines does not differ from that in the older. The success of the new engine is based on other circumstances—compression; ignition at the dead point; greater piston-speed; the use of diluted gas mixtures, made possible by the richer mixture in the admission port.

In conclusion, the Author calls special attention to this; that although Otto has mistaken the causes of the superiority of his engine, yet those are wrong who would state that the invention possesses no further merit. Surely to Otto must always be awarded the merit of creating the modern gas-engine from small beginnings by dint of his great industry and skill; and that is so great a merit that the very excusable mistake he made cannot detract from it. The Paper is illustrated by numerous figures.

D. C.

The Influence of the Walls in Gas-Engines.

By Dr. AIME WITZ, Lille, and Dr. A. SLABY, Berlin.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 690.)

Under this title Dr. Witz and Dr. Slaby state and defend the opposite conclusions at which they have arrived on the effect of the cooling walls upon the explosions which occur in gas-engine cylinders. Dr. Witz's Paper comes first, and he criticises Slaby's previous strictures upon his theories, remarking that he (Witz) is now supported in the correctness of his conclusions by many well-known technical and scientific men, including Professor Schottler and Mr. D. Clerk. He insists upon the importance and magnitude of the loss of heat caused by cold cylinder-walls in gas-engines, and adheres to his previous statement that, "It is necessary to transform the heat into work with the very greatest rapidity, and to reduce the duration of the contact between the hot gases and the cylinder walls to the smallest possible amount, while raising the cylinder temperature to the highest practicable point." By doing this, he says, the injurious effect of the walls upon the enclosed exploded gases is reduced to a minimum. The secret of economical action is found in a considerable initial compression,

high-temperature cylinder, and a high piston-speed. Tests were made with a 2-HP. Benz's gas-engine; diameter of cylinder, 5·5 inches; stroke, 11 inches. It drove a dynamo machine, the current from which passed through wires of constant resistance: the increase of speed gives accurately increase in power. It was invariably found that gas-consumption, for a given power, decreased with increasing temperature, the economy varying from 4 to 10 per cent. When the cooling water surrounding the cylinder was allowed to attain the temperature of about 70° C. (158° F.), the brake-power of the engine was maintained on a consumption of from 4 to 10 per cent. less gas than when the temperature of the cooling water was kept at about 18° C. (64·4° F.).

Similar experiments were made with a Simplex gas-motor of 8 HP. nominal, in Rouen and Paris. In Rouen, on November 7, 1885, temperature of cooling water 62° C. (143·6° F.), the engine made 154·3 revolutions per minute, giving 6·7 HP. on the brake, and consuming gas at the rate of 21·96 cubic feet per brake HP. per hour. When the temperature of the cooling water was raised to 74° C. (165·2° F.), 161·2 revolutions per minute were obtained, giving 8·67 HP. on the brake, and consuming 20·65 cubic feet per brake HP. per hour. This proves a saving of 7 per cent. The diameter of the cylinder was 7·87 inches, and the stroke 15·74 inches.

In replying to the foregoing statements of Dr. Witz, Dr. Slaby adheres to his previous strictures upon Witz's theories, and asserts that he can clearly point out wherein lies the fallacy, and prove by his own (Slaby's) experiments upon an Otto gas-engine, that not only does no economy follow high temperatures of water-jacket, and high piston-speeds of engine, but that a positive and easily-measured loss is occasioned by such departures from normal conditions. The engine used by Slaby was an Otto, rated at 4 HP. nominal; diameter of cylinder, 6·75 inches; stroke, 13 inches, and the volume of the compression-space was 0·61 of that swept by the piston. To ascertain the influence of the temperature of the walls of the cylinder, tests were made with the cooling water at the three temperatures of 16°, 60°, and 100° C. (60·8°, 140°, and 212° F.); a dynamometer was used to supply a constant load, and the power was measured by indicated diagrams, taken continuously, and carefully measured by means of a planimeter. Four experiments were made, the duration of three being forty minutes each, and the fourth, or control experiment twenty minutes, two hundred diagrams were taken in all.

The results are briefly as follows:—With the cooling water at 16° Centigrade, the unit volume of coal-gas gives in one experiment power proportional to 4·130, in another proportional to 4·073; with the cooling water raised to 60° Centigrade, unit volume of gas gives power proportional to 4·038, and when at 100° Centigrade, power proportional to 3·872. That is, increase of temperature of wall from 16° to 60° C. causes a loss of economy of about 2·2 per

cent. and increase from 16° to 100° causes a loss of about 6·2 per cent.

These experiments, says Dr. Slaby, prove in the most forcible manner the advantage of keeping the cylinder cool, and the disadvantage of allowing it to become hot; and they agree substantially with similar experiments carried out in conjunction with Professor Schottler. A little consideration will show that this is what theory shows to be correct; the efficiency of a cycle in any heat-engine depends upon the ratio between the highest and lowest temperatures, it is $\frac{T^1 - T^2}{T^1}$ when T^1 is the highest temperature (absolute), and T^2 is the lowest temperature. Now if the lowest temperature T^2 is increased, while the highest T^1 remains constant, the efficiency of the cycle at once diminishes. This is what is done by allowing the cylinder to become hot; the gaseous charge is heated while it should remain cool, and so loss is caused. The loss is calculated out, and it is found that heating the charge while entering the cylinder to 80° C. (176° F.), from 16° C. (60·8 F.), causes a loss of economy, theoretically, of from 6 to 7 per cent., corresponding closely with the numbers found by his (Dr. Slaby's) experiments.

Dr. Slaby does not question the accuracy of Dr. Witz's experiments, but considers the contradiction to arise from Witz's use of brake instead of indicated measurement of the variation of power; the indicator, he says, is the only reliable means of determining the change of power acting on the piston. He found similar results to Witz when testing by brake, a gain of 9·5 per cent. effective was obtained by allowing the temperature to increase from 16° to 60° C. (60·8° to 140° F.); that is due (he says) to the diminished friction of the engine at the higher temperatures. Four experiments were made with varying piston-speeds which prove that increase of piston-speed is not a benefit as formulated by Witz, but is an evil, and causes loss of efficiency instead of gain. The results are as follow:—With the engine making 102·6 revolutions per minute, the power given by unit-volume of gas is proportional to 4·031; at 151·8 revolutions, unit-volume gives 3·970; at 191·2 revolutions, unit-volume gives 3·952, and a control experiment at 92 revolutions, unit-volume gas gives power 3·976. Increase of speed of piston, therefore, causes an actual loss of indicated efficiency, mainly due to increase in negative work. In Dr. Slaby's opinion both of Dr. Witz's so-called laws are wrong and exactly contrary to facts, and constructors of gas-engines who follow them will find themselves in error.

D. C.

On the Theory of Combustion in the Gas-Engine.

By E. Körting, Hanover.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 737.)

The question of the nature of the combustion occurring within the gas-engine has been discussed by previous writers from an interesting, but purely scientific standpoint. In this Paper it is the aim of the Author to treat it from the practical side, and to see what can be done to aid the engineer in constructing an engine which will obtain from the gas used the maximum of efficiency; not only the highest indicated efficiency but the highest available work.

Every engineer knows that the greatest useful effect is produced in an expansion steam-engine by allowing the steam to be suddenly admitted at the dead-point, and suddenly cut off when admitted, without throttling during admission, or cut-off, or leakage after cut-off. Similarly, the best effect is produced in gas-engines by giving the maximum pressure rapidly while the piston is on the dead-point, and by adding as little heat as possible afterwards. The so-called "nachbrennen" or slow-combustion, should be avoided if possible, its action may be compared to that of a leaking slide-valve in an expansion-engine. Theory teaches that three things should be striven for :—

1st. The pressure should be developed at the highest possible speed, and all the heat added at once.

2nd. The previous compression should be as high as possible. The useful work obtained increases more rapidly than the increase of work compressing.

3rd. Cooling by the cylinder-walls should be avoided.

The compression on practical grounds must be limited to two or three atmospheres, and to prevent cooling is impossible, as the cylinder must be kept cool by water in order to work, and the difference between its temperature and that of the explosion can never be less than 1000° C. (1832° F.). As the cooling is a function of time, high piston speed is necessary to reduce loss; as cooling is also a function of surface exposed, the form of the cylinder should be such as to expose the least possible surface. Otto's engines, as well as Körting's, work by the cycle, discovered by Beau de Rochas, and experiments have been made to discover the best proportions of engine and dilution of charge. Otto considers it necessary to use air as a diluent, in addition to the products of combustion already existing in the compression-space. Here the Author differs from him, and takes in pure mixture of gas and air during the whole stroke of the engine, mixing it only with the inert gases already in the cylinder. Careful consideration shows that stratification is undesirable, and although

Otto describes it in his patent, he speedily discovered his mistake, and all his engines are so constructed as to avoid stratifying; they use, in fact, a uniformly diluted charge, which is really the best in practical work. Experiments made on Körting's engine, by igniting at four different positions, prove the mixture to be homogeneous and ignitable at any point; the diagram is practically the same from all. It was found, also, that high piston-speed gave the best diagram, and that little effect was produced by changing the direction of the inlet port.

The Author discusses at some length the points of difference between himself and Otto; also Slaby. The Paper is illustrated by numerous diagrams, and experiments in support of the views are described.

D. C.

On the Theory of Combustion in the Gas-Engine.

By Dr. A. SLABY, Berlin.

(Zeitschrift des Vereines deutscher Ingenieure, 1886, p. 325.)

The Author refers to Schöttler's discussion on this subject, and agrees with him in the necessity of dismissing, once for all, the dissociation theory, because of Mallard and Le Chatelier's experiments, but does not agree with him in likewise dismissing the "layerwise" stratification theory. He says that the failure to produce stratification in one model does not get over the admitted fact of its existence in the other model. He considers, also, that the fact of a side-valve acting badly in igniting the gases at the piston proves stratification in the Otto sense; but if more proof is wanted, it is supplied by some of the evidence in the English patent case of Otto *v.* Steel. Professor Dewar's evidence of the composition of the gases is given, in which it was stated that while 10 per cent. of gas was present in the mixture at the igniting-port, 7 per cent. was in the middle of the charge, and only 5 per cent. next the piston. Sir Frederick Bramwell took samples also, and found that those next the piston did not ignite. Mr. Schöttler could not get more complete proof of the correctness of Otto's theory. The Author differs from Schöttler on Dr. Witz's theories, and he considers that Witz is mistaken in his generalizations; indeed, that in practicable gas-engines the very opposite of Witz's conclusions more nearly accord with fact. Experiments are quoted in support of those statements.

D. C.

Experiments with an Otto Twin Gas-Motor.

By Heinrich Gollner.

(Technische Blätter, 1886, p. 10.)

The gas-engine forming the subject of experiment was of the Otto Twin type, of 8 HP. nominal, erected at the German Technical High School at Prague for the purpose of driving a number of electro-dynamic machines in the electro-technical laboratory.

Indicator diagrams were taken from each cylinder separately when the engine was unloaded, with both cylinders at work, and also with only one. The effective horse-power developed, measured by the brake, was determined for various pressures of gas. The indicated horse-power corresponding to the guaranteed effective work (8 HP.), was ascertained, and with the help of the indicator diagrams, taken when the engine was unloaded, the coefficient of additional friction K calculated.

The quantity of gas used and the initial and final temperature of the cooling water were observed, and analyses made of the products of combustion escaping from the cylinders.

The dimensions of the engine were as follows:—

Diameter of left-hand cylinder	171	millimetres . .	(6·73 inches).
„ right-hand „	170	„ . .	(6·69 „).
Stroke for both pistons	341	„ . .	(13·42 „).
Diameter of fly-wheel	1,800	„ . .	(5 feet 10·86 inches).
Width „ „	105	„ . .	(4·13 inches).
Number of revolutions per minute			180

Under otherwise similar conditions, the maximum power was developed with a gas-pressure of 25 millimetres (say 1 inch) of water; this amounted to 9·44 HP. (9·31 English HP.); a greater gas-pressure gave inferior results. The indicator diagrams taken from the right- and left-hand cylinders differed considerably from each other. That from the left-hand cylinder showed a maximum-pressure after the explosion of 12·75 atmospheres, while in the right-hand cylinder, it was only 7·5 atmospheres. This is ascribed to the difference in the explosive mixtures used for the two cylinders, which was proved by the analysis of the products of combustion from each. The expansion-curve in both diagrams approached very nearly to the adiabatic form, but lay somewhat below the latter in the left-hand diagram, and somewhat above in the other. The compression-curves in the two diagrams differed very considerably, that in the left-hand diagram being little above the adiabatic line, while that in the right-hand diagram was very slightly higher than the isothermal line. In both cases the initial pressure was the same, 0·875 atmosphere (absolute). As a result of these differences, the powers developed in the left- and right-hand cylinders respectively were 8·009 and 4·129 HP. (7·899 and 4·072 English HP.). The average consumption of gas, including the igniting flame, was 35 cubic feet per effective, or 23·03 cubic feet per indicated horse-power per hour. The ratio by volume of

air to gas in the explosive mixture was 9·884 : 1 and 9·565 : 1 with different gas-pressures. The ratio of effective to indicated horse-power η was 0·658. The comparatively low efficiency the Author ascribes to the high speed, heavy fly-wheel and unequal distribution of effort on the crank-pins. The temperature of the cooling-water was raised from 2·3° C. (35·6° F.) to about 44° (111·2° F.). It was found that when less power was required, either cylinder could be worked alone with good results. The coefficient of friction K, as used in the formula $N_i = N_o + (1+K) N_e$—where N_i = indicated power, N_e=effective power, and N_o=power required to drive engine unloaded—was found by calculation to be 0·0033.

The original is accompanied by copies of the indicator diagrams taken, and tabular statements of results.

G. R. B.

Temperature-observations at the Lake Superior Mines.

By H. A. Wheeler.

(American Journal of Science, vol. xxxii., 1886, p. 125.)

The copper mines of Keweenaw Point, Lake Superior, are now among the deepest mines in the United States, and therefore afford an excellent opportunity of determining the rate of thermal increase with descent into the earth. The usual gradient is 50 to 55 feet for an increase in temperature of 1° Fahrenheit; but exceptional gradients, higher or lower than this, have been observed in certain localities. The results of the Author's observations at Lake Superior were as follows:—

Mine.	Thermal increase in feet for 1° Fahr.	Vertical depth in feet.	Distances between rating stations in feet.	Highest temperature of mine in degrees Fahr.
Atlantic	99·5	907	796	51·6
Central	101·0	1,950	1,860	61·0
Conglomerate . .	95·0	617	527	48·3
Osceola	76·5	996	860	54·6
Tamarack. . . .	(110·7)	2,240	2,104	62·0
Quincy	122·0	1,931	1,820	58·5

The average thermal gradient is 100·8 feet to the degree, or, omitting the Tamarack results, 99 feet to the degree. The Tamarack mine, unfortunately, did not furnish stations that could be regarded as trustworthy, as they were too close to active mining operations.

While the average rate of these mines is exceptionally low, the variations among the different mines are very striking. The

nature of the rock in which the mines are worked does not offer any explanation, the greatest variations occurring in those worked in rock of the same character. The explanation is to be found in the proximity of the mines to Lake Superior. The mines nearest to the shore have the lowest gradient, whilst those farthest away have the highest. None of the mines mentioned are so far from the cold body of lake-water (38·8° F.), but that they still show the effect of its influence, notwithstanding the poor efficiency of rocks as heat-conductors. The Osceola mine, 5 miles distant from the lake, shows that this thickness of rock mass appreciably moderates the cooling action of the lake, and probably a thickness of 8 miles of strata would render its effect altogether inappreciable.

B. H. B.

Air-compressor at the Striberg Mines. By A. Larson.

(Jernkontorets Annaler, 1886, p. 267, 10 illustrations.)

During the years 1882-83, the air for the rock-drills in the Striberg mines was compressed in a Sturgeon steam-compressor. With this three rock-drills were kept continually at work; the expenses, however, were very great, amounting to £110 per annum, exclusive of rock-drills. In order to obtain more satisfactory economical results, it was decided to employ hydraulic power, and for this purpose to utilize a waterfall of 31 feet, 2,603 yards from the mine. A Gjers' turbine was employed for driving the air-compressor. The latter has two cylinders 11·34 inches in diameter, and 19·69 inches stroke, the fly-wheel making 100 revolutions per minute. The pipes conducting the compressed air to the mine are 2,603 yards in length, the greatest length of piping for compressed air in the whole of Sweden. The pipes are of cast-iron, 8 feet 9 inches long, 3·94 inches in internal diameter, and 0·59 inch thick; gutta percha rings, 0·16 inch thick, being used as packing between each length of pipe. In the mine, gas-pipes, 1·97 or 2·36 inches in diameter, are employed. According to observations made with manometers at the compressor and in the mine, the loss of pressure is not more than 4 per cent. During the two-and-a-half years the compressor has been in use, no repairs have been necessary, and the economical results have been highly satisfactory. In 1883, when the steam-compressor was employed, the cost of boring 1 yard was 2*s.* 5·89*d.* in ore, and 2*s.* 2·89*d.* in rock. In 1885 with the hydraulic compressor, the cost was 1*s.* 3·15*d.* in ore, and 1*s.* 1·21*d.* in rock, being a difference in favour of the present method of 1*s.* 2·73*d.* per yard in ore, and 1*s.* 1·68*d.* per yard in rock.

B. H. B.

Classifying-apparatus for Fine Ore at Raibl.

By J. Habermann.

(Berg- und Hüttenmännisches Jahrbuch der k. k. Bergakademien, 1886, p. 139.)

In the Raibl ore-dressing floors, there has recently been introduced a classifying apparatus for treating the ore from four fine-crushing rolls, and it has been found to answer its purpose remarkably well. The apparatus consists of three parts, a double cylindrical riddle, or trommel, and an ordinary trommel 9·84 inches in diameter, with an elevator-wheel between the two. The outer screen of the double trommel is 19·69 inches in diameter, and the inner one 15·16 inches at the end adjoining the elevator-wheel, and 14·18 inches at the other end. The trommels and the elevator-wheel have a common axis. The finely-crushed ore passes through a launder into the double trommel, the inner screen of which has holes 1 millimetre (0·04 inch) in diameter, and the outer screen holes 0·75 millimetre (0·03 inch) in diameter. Particles of ore more than 1 millimetre in diameter, that is, the ore that does not pass through the inner trommel, passes to the front, and is there raised by the elevator-wheel, and falls down over the conical nave of the wheel to the ordinary trommel in front. This is provided with a screen with holes 2 millimetres (0·08 inch) in diameter. With this arrangement for classifying, there are obtained particles 0·75, 1, 2, and 4 millimetres in diameter, each of these sizes being treated in a separate jigger. These are each provided with four sieves, in order to separate the galena and zinc blende. The plungers are driven by eccentrics, and have strokes of 0·24, 0·51, 0·79, and 1·02 inch respectively. The double trommel dips into water to a depth of 9·84 inches; the slimes being thus separated, and conducted to the buddles. The elevator-wheel is of cast-iron with V shaped arms. The apparatus makes 25 revolutions per minute.

The Paper is illustrated by two sections on a scale of one-twenty-fifth of the true size.

B. H. B.

Magnetic-Ore Separator. By J. Wenström.

(Ingeniörs-Föreningens Förhandlingar, Stockholm, vol. xxi., 1886, p. 5.)

This apparatus, for the concentration of magnetic iron ore, consists of a stationary electro-magnet supported by two spindle axes in a wooden stand. The magnet consists of an eccentric iron cylinder provided with flanges between which the conducting wire is wound in such a way that the current forms the north and south poles at the outer edges of the flanges, the adjacent flanges having different polarity. The current is conducted from a dynamo

into the apparatus by means of isolated wires through one of the spindles. Around the magnet a drum rotates on the spindles. The drum consists of a number of parallel soft-iron rods separated from each other by wood. The ore enters at the top of the drum, and follows its rotation; the non-magnetic portions falling after a quarter-revolution, and the magnetic ore being firmly held by the magnetic iron rods. After another quarter-revolution this falls into the ore-hutch. Ore intimately associated with gangue must, of course, be first comminuted and washed.

The first place in Sweden where this separator was adopted was the Hjuljern mine in the Nora district. Here the separator treats 104 cwt. per hour. In the month of September, 8,593 cwt. of washed ore were treated, giving 5,027 cwt. of ore, and 3,566 cwt. of deads, being a gain of 58·5 per cent. of ore. Seven workmen and five boys were employed; their wages amounting to £22 18*s.* 9*d.*, that is, 0·7*d.* per cwt. of ore treated. It is stated that in future the cost will be reduced to 0·5*d.* per cwt. For feeding the machine, lubrication and transporting ore and deads, the cost is only 0·13*d.* per cwt. The separated ore contains 57·5 per cent. of iron.

At the Kantorp mine in Södermanland the results obtained were as follows: During the fifty-one days the machine was in operation, 8,895 cwt. of ore were obtained, that is, 174 cwt. per day; the cost for 1 cwt. of ore being as follows:—Wages, 0·44*d.*; peat as fuel for the portable engine driving the machine, 0·20*d.*; lubrication, 0·03*d.*; total, 0·67*d.* The ore obtained was, in volume, somewhat more than half of the material treated. The deads were not weighed.

The paper is illustrated by three drawings of the machine on a scale of one-eighth of the true size.

B. H. B.

Purification of Water from the Dressing-floors of Mines.

By — Wittelsbach.

(Berg- und Hüttenmännische Zeitung, 1886, p. 369.)

The Author advocates the following method for clarifying the water from dressing-floors: Every dressing-floor has its waste-heap, on which the waste from the jiggers is emptied, the particles varying in diameter from 0·79 to 0·02 inch; whilst the finer particles pass away with the water and form mud. No better filter than this waste heap could be desired for clarifying the muddy water. On the level surface of the waste heap, two or more shallow pits are dug 19 to 23 inches deep, and as wide as the heap will allow, their length varying according to the quantity and degree of concentration of the liquid. Into these pits is run all the muddy water from the dressing-floor. The water will begin at once to filter through the heap, and flow away quite clear

through a channel in the deepest portion of the valley, whilst the slimes are deposited on the surface. Very soon, however, the channels become stopped up, and on the heap a shallow pond is formed in which the heavier and coarser particles subside, whilst the supernatant liquid retains the finer particles. This is then conducted into the next pit, where it sinks through the waste heap, and is completely clarified. The sand filter of the second pond will not become stopped up if care is taken that all the heavier particles remain in the first pond. If, however, it finally becomes useless, it is merely necessary to dig a fresh pit.

It is advisable not to make the pond too deep, because in deep water currents easily arise and prevent subsidence, and because stronger sides would be necessary on account of the pressure of the water. In many dressing-floors the level of the waste-heap is higher than that of the apparatus for concentrating the ore. In this case, the muddy water must be raised mechanically, and the operation may advantageously be combined with a further washing of the mud. In addition to clarifying the water, and depositing the mud without cost, the proposed utilization of the waste-heap has the further advantage that it makes it impossible for the sands to be blown over cultivated lands, as the surface of mud becomes caked together, and does not split up even with great heat and dryness.

B. H. B.

The Herbertz Foundry-Cupola. By C. Brandenburg.

(Annuaire de l'Association des Ingénieurs sortis de l'École de Liége, 1886, p. 259.)

The Herbertz cupola is the joint design of Mr. Herbertz, of Cologne, and his engineer, Mr. Sahler. In order to avoid the noise of a fan, and the danger of scattered sparks and cinders, the draught is effected by means of a steam-jet, much as in the Woodward cupola, but arranged at the side, and leading into a chimney 82 feet high, while the charge is introduced through close-fitting hopper doors at the top. The interior diameter of the cupola is 2 feet 3½ inches at its narrowest part, 2 feet 9½ inches at the zone of fusion, and 3 feet 1½ inch at the hearth, which is about 1 foot 10 inches high.

As the result of various trials appeared to indicate that economy in working was increased in proportion to the multiplication and subdivision of the orifices for admitting the air, the following arrangement was finally adopted. The main body of the cupola is suspended by clamps from four hollow cast-iron pillars, which also serve to carry the charging stage. Each of these columns is furnished with a central screw, worked by a hand-wheel on the top, and these screws carry nuts, which, by means of projections through slots in the lower parts of the columns serve to support the lower portion, or "hearth" of the cupola, with its tapping-hole

and spout attached. By this means, a blast-orifice of variable width, extending continuously round the circumference is provided, while for cleaning, or for extensive repairs, the hearth can be lowered entirely. The usual width of this blast-orifice is ⅝ inch, but it is found desirable to modify it to suit different qualities of coke. The steam-jet is ⅜ inch in diameter.

The results obtained from this cupola during a period of nine months have been very satisfactory, about 3 tons per hour being melted at a high temperature. In working, from 3 to 4 cwt. of coke are used for lighting up, then alternate charges of 1 ton of pig and 3 qrs. of coke are introduced, this being the usual proportion of coke to pig, as compared with 1½ to 2 cwt. of coke per ton of pig in cupolas of ordinary construction. This requires 150 lbs. of steam per hour, equivalent to a consumption of 22 lbs. of coal, or say 8 lbs. per ton of iron melted. The waste gases are not used for firing the boiler.

With a steam-pressure varying from 50 to 66 lbs. the partial vacuum, measured 3 feet 3 inches above the intake of air, corresponds to a depression of from 1·57 to 2·36 inches on the water-gauge; and, when the intake is closed, to a depression of 3·35 inches. While the hopper is open for introducing a charge, this falls to 1·18 inch. A better result is obtained when the cupola has been at work for some time than at the commencement, owing probably to improved draught as the chimney becomes hotter. The draught of the chimney alone corresponds to a depression of 0·39 inch on the gauge.

The molten iron begins to come down five minutes after the jet is turned on, and the waste, which usually amounts to from 7 to 9 per cent. of the pig, is insignificant; this the inventors attribute to the regularity of the temperature at the zone of fusion, so that, while the iron is brought to a uniformly high temperature, it is never overheated or burnt. The castings produced are very pure, soft, and strong, even when inferior cheap pig, such as No. 3 in Luxemburg, is used.

Mr. Ad. Gurlt, of Bonn, suggests, as an explanation of the success of this process, that in the ordinary cupola, with blast at a pressure of from 8 to 10 inches on the water-gauge, the compressed oxygen readily and speedily combines with the carbon to form carbonic acid (CO_2), which in the upper part of the cupola is partially reduced to carbonic oxide (CO), with a corresponding fall of temperature and imperfect heating of the cold charge, besides a considerable loss from the imperfect combustion of part of the gas. But in the Herbertz cupola, with air at atmospheric pressure admitted round the whole circumference, the complete combustion of the coke and its transformation into CO_2 is slower; while the free oxygen, penetrating to the upper layers, causes a combustion which thoroughly heats the cold charges, and the carbonic acid (CO_2) once produced has no opportunity to be transformed to CO, and carry off unburnt carbon. Moreover the free oxygen combines with the 2 per cent. of silicon contained in the pig, which is refined

and purified, while the combustion of the silicon raises it to a high temperature.

On one occasion, when the boiler was laid off for repairs, the cupola was worked with merely the chimney draught. On the first day only 1 ton was melted, 2 tons on the second, and 3 tons on the third. The first tapping, though sufficiently liquid, was rather cold, but the third was quite hot enough; and although the time occupied was double that required with the steam-jet, the economy of coke was still very noticeable.

The Paper is illustrated with an engraving of the Herbertz cupola. W. S. H.

Open-hearth Steel-making without Scrap.

By E. G. Odelstjerna.

(Jernkontoret's Annaler, 1886, p. 77.)

The Author has been engaged for the last four years in experiments on the possibility of making Siemens steel in the open-hearth furnace with pig-iron and iron-ore alone, without the use of scrap steel or iron. The first experiments were made at Nora Hammarby, and the method has subsequently been adopted for a 4-ton furnace at Ankarsrum, one of 8 tons at Hellefors, and one of 3 tons at Söderfors. The furnace is of the ordinary open-hearth form, as constructed by the Author, with steeply-inclined gas- and air-passages, which are placed side by side at the same level; but the roof is domed in the centre, as in Mr. Frederick Siemens' new furnaces. The hearth-bottom is made of quartz, finely crushed, and moistened with pure water, which is covered by a layer of quartz bricks, 4 centimetres thick, the interstices being packed with quartz, mixed with water alone, or with a small quantity of clay. The bed is made up of layers, which are subjected to a strong, clotting heat, the exact details of which can only be learnt by practice. The first firing requires from one to one and a half days. The thickness of the fritted working bottom is about 8 centimetres (3·15 inches) in a new furnace. The depth of the bath in an 8-ton furnace is about 30 centimetres (12 inches) as a maximum. The tap-hole is about 8 centimetres in diameter, is sharply inclined, partly to allow the metal to run as low as possible into the ladle, but more particularly to give a free passage for the slag, which is often very thick, and otherwise would require to be raked out, which is very fatiguing work for the furnace-men.

The whole amount of pig-iron is charged at once, and melted down in about two hours' time. Ore is then added in large lumps to the extent of about 10 per cent. of the weight of the metal. The reaction commences as soon as the ore is melted, the slag being blown up with small bubbles of gas. In about one and a half or two hours the ebullition ceases, the level of the bath subsides, and

the slag, when tested, is found to be of a light yellowish green colour, and free from bubbles. After a fresh addition of ore, in smaller quantity than the first, the boiling recommences, but more violently than before, the bubbles being larger, and the surface is covered with light blue carbonic oxide flames; a third addition produces a still more violent action, the bubbles being at times as much as 12 inches in diameter, and the slag boils over into the hanging holes of the furnaces. This very active boiling rarely lasts more than a quarter of an hour. The finished metal is subjected to a forge-test in the usual way, and manganese is added, when necessary, to correct red shortness before cooling.

The time necessary for working the charge is longer than that required when scrap is used. This is due mainly to the large quantity of slag that forms towards the end of the process, and prevents the later additions of ore from readily coming in contact with the metal, so that the refining action is retarded. The slag is comparatively poor in iron, and very tough, so that it cannot be tapped off during the process. If this could be done the time might be considerably reduced, but up to the present time the trials have not been successful.

The Author gives the details of a great number of operations made in the different works employing the process, with charges varying from 34 cwts. up to 4 tons, the products being steel of various tempers, from 1·25 per cent. of carbon down to very soft iron with only 0·04 per cent., while the time of working varied from four and a quarter to eleven and a half hours. The ore used must be exceedingly pure and rich in iron. In the first trials the best ores from Timansberg and Pershytte were used, the former, a magnetite, with about 70 per cent., and the latter, a specular hæmatite, with 65 per cent. of iron, when it was found that the consumption for equal weights of pig-iron treated was in the proportion of 100 of magnetite to 133 of hæmatite. Ores from other localities, with 60 per cent. of iron and upwards, have been adopted in practice, according to the position of the localities; but it is important that they should be as free as possible from earthy matters and pyrites. The ore is added in lumps of the size of a man's head, which, at the full heat of the furnace, melt down in from five to ten minutes. In one instance the ore, broken to the size of walnuts, was placed in the chill moulds, in which the metal from the blast-furnace was cast. When these pigs were run down the ore-lumps remained unmelted for about an hour, but the original contents of silicon, which was 1·28 per cent., was reduced to 0·3 per cent., the carbon remaining unchanged at 4 per cent. After the ore was melted, and the boiling of the slag had ceased, carbon was reduced to 2·9 per cent., and silicon to 0·02 per cent., in which state the test-metal, when broken, resembled spiegeleisen. Two further additions of ore, each of 2 cwt., were required to bring the 44 cwt. of metal charged to the required temper (1·25 per cent. carbon), the whole operation lasting eight hours thirty-five minutes, or longer than when the ore was added to the

pig metal previously melted. Later experiments, however, seem to show that an intimate mixture of the metal with finely divided ore, such as that of the Ellerhausen process, may be advantageous in shortening the time required for the process.

The average amount of ore required has been about 24·46 per cent. of that of the pig-iron, when the finished metal contains about 0·2 per cent. of carbon. At Hammarby, however, the average consumption has been only about 18 per cent. The yield of ingots is about the same, or a little less than that of the pig-iron, so that a proportion of the iron in the ore is recovered; the bulk, however, passes to the slag.

The following Table shows, by detail, the measures of the operations in one of the charges, as well as the charges in the product at the different stages. It refers to charge No. 46 at Hammarby; the ore used is the best Timanberg magnetite.[1]

Time.	Pig Iron.	Ore.	Ferro Manganese.	Composition of Product.				
				C.	Si.	P.	S.	Mn.
	Kilogs.	Kilogs.	Kilogs.					
8.50 A.M.	3,827 (8,719 lbs.)	..	..	..	..	..	..	..
10.50 „	melted	..	..	3·6	0·28	0·029	0·01	trace
12.20 P.M.	..	..	..	3·4	0·27	0·029	0·01	..
12.25 „	..	325	..	..	..	..	..	..
2.50 „	..	..	..	2·5	0·09	0·030	trace	trace
2.55 „	..	250	..	..	..	..	..	..
4.15 „	..	..	..	1·8	0·01	0·031	trace	trace
4.20 „	..	200	..	..	..	..	..	..
5.10 „	..	..	..	0·9	0·01	0·031	trace	trace
5.15 „	..	150	..	..	..	..	..	..
6.10 „	..	..	..	0·25	0·02	0·031	trace	trace
6.15 „	..	60	..	..	..	..	..	..
7.00 „	..	..	2	..	..	..	..	..
Cast 7.10 „ Ingots 3,790 kgs. (8,338 lbs.)	..	..	..	0·04	0·01	0·030	trace	0·02

The quality of the metal is exceedingly good, and is in every way equal to that made with the best Swedish scrap. With even the minimum of carbon (0·04 per cent.), no difficulty is experienced in casting if care be taken to keep the furnace properly heated.

At Surahammer an experiment was made with the process, using one from Grängesberg, containing a notable amount of phosphorus. 425 kilograms (930 lbs.) of pig-iron were melted down, and after sampling, 194 kilograms of ore were shovelled into the furnace. The operation, which lasted three hours and twenty minutes, gave 452 kilograms (994 lbs.) of ingots and 320 kilograms (704 lbs.) of

[1] Assuming this to contain 70 per cent. of iron, it appears that of the total of 679 kilograms contained in the ore, 113 kilograms are reduced in the ingots, while the remainder (about 87 per cent.) passes into the slag.

slag. These products, when analysed, showed the following proportions of phosphorus :—

In the pig iron	0·028 per cent.
„ ore	0·80 „
„ ingots	0·126 „
„ slag	0·009 „

Whence it appears that in the open-hearth furnace the greater part of the phosphorus contained in the ore passes into the metal.

The Author gives illustrations of the furnace, and of two forms of gas-producers, one for use with peat or wood, and furnished with a condenser, and the other for coal, many of which are in use in Sweden and Finland. The domed construction for the roof has been used by the Author since 1879, but the method of placing the gas and air parts side by side at the same level is considered to be the most advantageous. A furnace of this sort at Värtsilä, in Finland, was lately altered for the basic process, and the ports were changed so as to lay the air in above the gas, but it was found that the heat obtained was not so good, while the consumption of gas, and consequently of fuel, was increased, and consequently they were restored to the original form.

H. B.

A New Material for the Siemens-Martin Process of Steel-making.

By O. Murisier.

(Gorny Jurnal [Russian Mining Journal], 1885, p. 85.)

The Author begins by pointing out the advantages of the Siemens-Martin process in economy of first cost, in the greater certainty of the results, and in the facility with which large or small charges can be worked. The process, however, requires from 55 per cent. to 70 per cent. of wrought iron or steel scrap, which is difficult to obtain in sufficient quantities at a distance from large towns, or great railway lines, and this difficulty has had the effect of greatly restricting the application of the process. To overcome this obstacle attempts are continually made to use the crude ores direct in the furnace, but the greater number of ores, those containing much phosphorus, or much silicon, are not suited for the process.

About the year 1875 the Finnish engineer, Mr. Hushavel, contrived a furnace which combined the properties of the open-hearth furnace and the blast-furnace, which was continuous in its action, and by means of which he was able to produce any quality of cast steel direct from the ore.

Mr. Murisier, who, in 1880, was managing the Pontiloff Steel Works at St. Petersburg, happened to hear of Mr. Hushavel's process, and was able to give the metal he produced a trial by substituting it for scrap in his Siemens-Martin furnaces. At that time, however,

the process of dephosphorization in the Siemens furnace had not been put into practice at Mr. Murisier's works, so that the exclusive use of the new material, which contained from 0·08 to 0·1 per cent. of phosphorus, was impossible.

In 1884 Mr. Hushavel had greatly improved his furnace, and the metal produced direct from the lake ores was re-melted and dephosphorized on a large scale in the Siemens furnaces with the best results. Nearly 2¾ tons of metal were produced in twenty-four hours from each furnace, 100 tons of metal being the produce of 318 tons of ore, and 104 tons of coal. With ore at 11*s.* 4*d.* per ton, coal at 12*s.* 7*d.*, lime at 3*s.* 2*d.*, the metal was produced at 70*s.* 3*d.* per ton, including establishment charges, being about the cost of pig-iron produced at the Viartzil Works, where the experiments were made in blast furnaces of 2,646 cubic feet capacity. The ore contained from 28 per cent. to 42 per cent. of iron, 15 per cent. of silicon, 0·3 per cent. to 0·8 per cent. of phosphorus, and 12 per cent. of moisture. 36 per cent. of pig-iron is obtained on the average from these ores in the blast-furnace.

Besides the metal produced from the ore alone, about 2½ tons per day was produced from a mixture of 60 per cent. of ore, and 40 per cent. of slag from the puddling-furnaces, and 1½ ton per day from the slag alone. The resulting forged material contained from 0·18 per cent. to 0·77 per cent. of phosphorus, and from 0·1 per cent. to 1·2 per cent. of carbon. This variation was of no consequence in metal destined to be worked over again in Siemens-Martin furnaces. Experiments have shown that by Mr. Hushavel's process very considerable regularity is capable of being attained.

The results of working fourteen charges in Siemens-Martin furnaces of 5 tons capacity in April 1885, with proportions of the new metal gradually increased to 66 per cent., were highly satisfactory. No injurious effect was produced on the dolomite fettling of the furnace, the metal produced was of excellent quality, and free from every symptom of red shortness, the loss in the furnace, amounting to from 14·8 per cent. to 20·06 per cent., did not increase with the increase of the quantity of Hushavel's metal.

The Paper concludes with a review of the condition of the Siemens-Martin process in Europe and America, and cites a remarkable case communicated to the Author by Mr. Gilchrist, of the Brymbo Basic Siemens-Steel Company, where pig-iron containing as much as 3 per cent. of phosphorus is satisfactorily dealt with.

W. A.

On Liquation-phenomena in White Cast-iron. By B. Platz.

(Stahl und Eisen, 1886, p. 244.)

The subject of the separation of grey cast-iron into substances of varying composition by liquation in cooling having been investigated by Professor Ledebur ("Stahl und Eisen," 1884, p. 634),

the Author points out that a similar kind of separation takes place at times in the solidification of white iron, and especially of spiegel which has been superheated before cooling. Low spiegel with 5 to 7 per cent. of manganese made for forge purposes often contains hollow spaces, which are filled with thin leaf-like crystals not more than 0·1 millimetre thick. In many cases these plates are of variable thickness, being broad at their attachment to the side of the cavity, and tapering to extreme thinness in the middle. When freshly broken the plates have bright mirror-like surfaces that soon tarnish when exposed to the air; but the film of oxide formed is so extremely thin that it may be disregarded in the analysis. Three samples of these crystals, and of the bulk of the metal upon which they were formed, have been examined by the Author, and in each case a notable difference in composition was indicated by the analysis, as will be seen below.

	I.		II.		III.	
	Crystals.	Bulk.	Crystals.	Bulk.	Crystals.	Bulk.
Si . . .	0·260	0·395	0·229	0·521	0·101	0·313
P . . .	0·171	0·525	0·378	0·591	0·272	0·561
Mn . .	6·570	6·120	6·970	6·008	6·380	5·872
C . . .	4·808	4·391	4·768	4·376	4·627	4·283

In each case it will be seen that the action is similar, the crystals containing less silicon and phosphorus and more manganese and carbon than the bulk of the metal from which they have separated. There is also a noticeable difference in the behaviour of the two substances when treated with hydrochloric acid. White cast-iron on solution gives a voluminous brown residue, containing carbon, silica, and iron; and a similar residue was obtained in each case from the bulk of the metal, while the crystals dissolved with a separation of pure silica free from either carbon, iron, or graphite. It would appear, therefore, the carbon in these crystals was entirely a combination. Ledebur considers that the presence of numerous foreign substances in cast-iron facilitates its separation into alloys of different melting-points, which explanation the Author considers to be applicable to the case under discussion, as the crystalline plates, being freer from silicon and phosphorus, may serve a higher melting-point than the bulk of the metal from which they have separated during slow cooling in the interior of the mass. It may be, however, that the existence of free space in the hollows is the actual determining cause of the separation. It has been long known that silicon is prejudicial to the formation of spiegel, that is, to crystallization, by displacing carbon, and inducing an equivalent separation of graphite. About 0·5 per cent. appears to be the critical limit for silicon as regards this action. Spiegel with more silicon and free from graphite is obtained sometimes, but only exceptionally. It has also been generally supposed that phosphorus acts in a similar manner, and this latter proposition the Author considers to be established by his investigations.

H. B.

The Parting-Process used in the United States Mint.

By T. Egleston.

(School of Mines Quarterly, April, 1886.)

The parting-process in use at the United States Mints in Philadelphia and San Francesco, was invented by Mr. A. Mason, of the New York Assay Office, in 1866. It is known as the double process, both nitric and sulphuric acids being used. The bullion alloyed with silver so as to contain 100 of gold in 285 of total weight, is granulated and treated with nitric acid, which removes the silver to within 6 per cent.; after which it is twice boiled with sulphuric acid, giving gold of 998 fine. The process is applicable to all kinds of alloys, and is much cheaper than the old method of using nitric acid alone, as less fuel is required, and the consumption of nitric acid is reduced by 20 per cent.

The process includes the following eight operations:—

1. Receiving and melting deposits.
2. Inquartation and granulation of the material containing gold.
3. Solution of the granulations in nitric acid.
4. Finishing-parting in sulphuric acid.
5. Conversion of silver nitrate into chloride.
6. Reduction of silver chloride.
7. Washing and pressing silver into cakes and drying parted gold and silver.
8. Melting and casting refined gold and silver.

1. The deposits received at the Mint include gold and silver bullion of all kinds, and worn, broken, and old-fashioned jewellery, anything being received, except it contain tin, which is as much as possible rejected. Much of the cheap gold jewellery filled with solder, and watch-cases alloyed with tin, are in the latter condition. The refining of such metal is troublesome, and requires appliances not included in the Mint-plant. Each deposit is melted and assayed separately, Hessian crucibles of about 200 ounces capacity being used for gold, and blacklead crucibles for silver. The former lasts about five rounds of melting, and the latter about one hundred, or a week's work. Anthracite is used for melting large lots, and charcoal for small ones. When the metal requires softening, it is covered about one-sixteenth of an inch deep with bone-ash, and nitre is added as an oxidizing flux, through holes made in the cover. This operation is renewed two, or even three times, if the metal is very impure. When it is sufficiently prepared, the cover is removed, and the final fluxing is effected with borax.

Silver bullion from New Mexico, containing antimony and arsenic, is refined by briskly stirring it when melted, with an iron bar, for two or three minutes, with an addition of nitre. When iron and sulphur are present, a flux of one part of sand and two of nitre is used. Sal ammoniac is employed for the removal of tin or

other substances difficult to separate, and soda and salt to thin the slags when they are too thick. When the metal is ready for pouring, it is vigorously stirred with a graphite stirrer, held in the tongs, so as to thoroughly mix the contents of the crucible before cooling. This is found in almost all cases to give ingots of sufficiently uniform composition throughout.

2. *Inquartation and granulation of gold.*—This is done once a week, the general ingot-melting is done every day in which the coinage bars are made. There are eleven melting-furnaces of the capacity of 3,500 ounces of standard silver, or 6,700 ounces of gold, and taking No. 70 graphite crucibles, which stand twenty-four rounds with gold, and thirty-six with silver. The silver bars weigh from 20 to 180 ounces, and those of gold 100 to 200 ounces. Gold intended for parting is alloyed with the required amount of silver, and granulated by pouring it when melted, from a height of seven or eight feet, into a copper pan containing water cooled with ice. Auriferous silver in bars is not granulated, but sent to the parting-house.

3. *Nitric acid solution.*—The first parting of the granulated metal is effected in parting-pots or corroding-jars made of glazed earthenware, 24 inches in diameter, and 21 to 22 inches deep, weighing about 90 lbs. When in use, they stand upon wooden gratings in a tank lined with lead, and filled to a depth of ten inches with water. The water is heated to boiling by perforated copper steam-pipes round the sides of the tank. The charge of granulated bullion, weighing 128 lbs., is covered with five pitchers of 25 lbs. each, of nitric acid at 40° Beaumé, steam is then turned on, the contents of the pot are kept boiling for twelve hours. To prevent clotting, the granules must be stirred with a wooden paddle for about a minute, at intervals of twenty minutes. No covers are used on the pots, as they are enclosed in a wooden house pitched on the inside, having a flue at one end connected with a stack 120 feet high, which carries off the acid vapour. The charge, after remaining in the pots overnight, is diluted with water and heated for a short time to dissolve any crystals of silver nitrate that may have separated, and the solution is drawn off by a gold siphon into wooden tubs 18 inches in diameter and 15 inches deep. Three pitchers of fresh acid are then added, and the boiling is continued for another twelve hours, followed by twelve hours of rest as before. This second acid not being saturated, it is put aside to be used in the next fresh charge. When the acid is boiled down so far that crystals of silver nitrate form, water is added to dilute it, and the whole is siphoned off. The pot is then lifted out, and the gold is washed on to a filter made of Swedish filter-paper between two thicknesses of muslin. This is supported upon a perforated false bottom, in a wooden tank 21 inches deep, and is 24 inches in diameter at the bottom, and 28 inches above. The charges from eleven pots form a layer of about one foot thick upon the filter. The washing with hot water is continued for about two or three hours, the drainings being

received in the large silver-liquor tank. When perfectly washed, the gold is removed from the filter by porcelain scoops. The upper muslin cover of the filter lasts out two and the lower one three operations.

4. *Sulphuric acid parting.*—This is effected in three-legged cast-iron pots with trunnions on the sides. They are nearly hemi-spherical in shape, 22 inches in diameter, and 12 inches deep. They are set in holes bordered with conical flanges, in the covers of the boiling-furnaces, above which they project about 7½ inches, and are covered with conical hoods of sheet lead, leading into a reservoir which connects with a lead-lined tank, above it communicating with the terra-cotta pipe in the ventilating-flue of the parting-house. Any acid that may be condensed is caught in the tank and collected by a drain at the corners; the remainder escapes to the chimney. The contents of the pot are accessible during the operation by means of a sliding-door in the lead-covered hood. The furnace is fired with anthracite. The charge of gold, consisting of ten ladlefuls 6 inches in diameter, and 4 inches deep, is treated with 32 lbs. of sulphuric acid of 66° Beaumé, and boiled for one hour and a half, by which time it has nearly evaporated; a second similar quantity is added and boiled for the same time. The pot must be stirred every ten or fifteen minutes to prevent the gold from clotting on the bottom. This is done with a four-pronged iron rake, introduced through the sliding opening in the hood. After the second boiling, the gold is from 996 to 998 fine, but it may be brought up to 999·5 by a third boiling. The excess of acid is poured off to be used again, while that that is evaporated is condensed in a lead-lined tank. The gold, after being carefully washed with water, is collected in a porcelain pot, and kept under water until the lot is worked off, when it is filtered upon two thicknesses of filter-paper, and a single thickness of muslin on a frame 20 inches square. When washed, it is sent to the drying-furnace.

5. *Conversion of Silver Nitrate into Chloride.*—The nitrate-solutions from the eleven parting-pots in use are transferred to a wooden tank 10 × 8 feet and 4¼ feet deep, where the silver is converted into chloride by means of common salt, in the form of saturated brine, which is prepared in a tank on the floor above, and is run in to a depth of one foot on the bottom of the tank. The whole is stirred by a wooden dasher with a long handle. About two hours are required to completely precipitate the silver from the acid liquor of the corroding-jars. The contents of the tank are accessible from a platform, which can be moved about over-head. When the tests show that the liquor is free from silver, the bulk of the precipitate is pushed towards the discharging-spout, which projects over a tank upon a wagon. The bottom of the tank is perforated with ¼-inch holes, and, together with the sides, it is covered with twilled cloth. The heaviest part of the precipitate is pushed on to the cloth, forming a bottom about two or three inches thick, which is sufficiently compact to prevent the finely diffused particles of chloride in the mass of the liquor from passing

through. The filtrate produced in the washing is collected in pails and returned to the precipitating-tank. The chloride is washed with water for about four hours, the washings passing through two or three traps into the receiver.

6. *Reduction of Silver Chloride.*—The silver chloride when completely drained, is reduced by means of granulated zinc in a tank 6 feet × 3 feet 9 inches and 18 inches deep, lined with lead, with rounded corners at the bottom to facilitate stirring. Two boxes containing 32 lbs. each of granulated zinc are usually sufficient to reduce the silver from eleven charges of the solution-pots, but sometimes rather more is required. The chloride is shovelled out of the vat upon wheels by a copper scoop, thrown into the tank first, and the zinc stirred up with it afterwards. Usually the reduction commences at once, but if not, about a pint of sulphuric acid is added to start it, a wooden shovel with a blade 17 inches, tapering from 2½ inches thick to a sharp edge, is used for stirring. This must be done very actively for the first hour, and afterwards occasionally during the three hours following. The operation is finished in four hours. If the reduced silver is very dry, water is added to dissolve out the zinc sulphate. The operation is now performed in an open tank, a cone-shaped leaden hood previously in use having been removed as inconvenient and dangerous in manipulation. No great inconvenience is felt by the men from the gases evolved. When there is no further action, three pitchers of 32 lbs. each of sulphuric acid are added to dissolve the excess of zinc. The vat is allowed to lie all night with the acid in it. The reduced silver is then pushed to one side, and the liquor in excess is drawn off by a copper siphon.

7. *Washing, pressing, and drying Silver and Gold.*—The reduced silver is removed by a copper scoop to a wooden colander 3 feet in diameter and 20 inches deep, to the false bottom, which has a clear space of 6 inches below it. The false bottom is covered with twilled cloth, and the silver is filled to within four inches of the top of the colander, and washed with hot water until it is perfectly pure. It is then transferred to a circular mould 12 inches in diameter, and the same depth, and consolidated first by a wooden stamper, and subsequently by the ram of the hydraulic press, which fits the mould rather loosely. This produces a cake about 4 inches thick, about a gallon of water, which is passed through the filter, being expelled during the pressing. The cakes are dried upon a pan made of boiler-plate 7 feet by 38 inches and 4 inches deep, heated by a wood fire below, and covered with a rectangular hood with a pipe for conveying steam to the chimney. The silver cakes, which shrink considerably in drying—as much as 2 inches upon the diameter of 12 inches—are piled up in two rows of six each upon copper trays, care being taken to keep them out of contact with the copper sides.

The gold-drying furnace is similar in character to that used for silver, but smaller. An iron shovel and copper scoop are used both to introduce and remove the gold, which contains very little dust,

as that obtained from sulphuric-acid parting is generally coarse. The fire-place of the furnace is 14 inches square; it has no grate, but the ends of the sticks used rest upon iron in front and brick-work behind. Three fillings of the furnace full of wood are required for drying silver, and one and a half for gold.

8. *Melting and casting Gold and Silver.*—The ingot-melting room contains eleven melting-furnaces, one of which is reserved for granulations. Graphite crucibles are used, which can be lengthened by rings of the same material, 3 inches deep, cemented on to the top by borax and silica, when extra capacity is required for holding long ingots or bricks of metal. When the melting is finished, the ring can be removed by prizing it off with a poker. The time of melting is one hour ten minutes for silver, and one hour and three quarters for gold, anthracite being used exclusively in the furnaces. The pots are very thoroughly stirred, iron stirrers being used for silver, and graphite for gold. Six tons of standard silver bars may be cast in thirteen hours, keeping six furnaces at work. The loss of weight is estimated at one-tenth of an ounce per thousand ounces melted. Besides coin, there are made silver bars of 999½ fine, from 20 to 180 ounces in weight, and gold bars, 999 fine, from 5 to 243 ounces, which are stamped with their fineness, weight, and value, and pass current in the same way as larger bars and bricks do in New York.

The latter part of the Paper contains details of the mintage and refining charges, and details of the cost of working in 1884–5.

The following Table gives the legal weight, fineness, and dimensions of the United States coins, gold and silver, at present in circulation:—

	Weight.	Fineness.	Diameter.	Thickness.
Gold—	Grains.	Thousandths.	Inch.	Inch.
Double eagle . (20 dollars)	516	900	1·35	0·077
Eagle . . . (10 „)	258	„	1·05	0·060
Half eagle . (5 „)	129	„	0·85	0·046
Three dollars.	77·4	„	0·80	0·034
Quarter eagle (2½ „)	64·5	„	0·75	0·034
Dollar (new)	25·8	„	0·55	0·018
Silver—				
Trade dollar	420	„	1·50	0·082
Standard dollar	412·5	„	1·50	0·080
Half dollar	192·9	„	1·20	0·057
Quarter dollar	96·45	„	0·95	0·045
Twenty cents	77·16	„	0·875	0·047
Dime	38·58	„	0·70	0·032
Half dime	19·2	„	0·60	0·023
Three cents	11·52	„	0·55	0·018

H. B.

Corrosion of the Copper of the "Juniata." By C. E. Munroe.

(Proceedings of the United States' Naval Institute, 1886, p. 391.)

In October 1882, the "Juniata" was in dry-dock, and, on examination of her copper, it appeared that the immersed surface had become covered with a pale-green, earthy-looking coating, which at the time had become dry in spots, and blistered. Many of these blisters had split, and the coating had flaked off to such an extent that the floor of the dock was thickly strewed with them. The inner surfaces of these scales were in the main of a copper-red colour; but in some spots they were black. In addition to this general action, several plates had been so corroded as to be nearly, or completely, perforated; and appeared to be laminated. The evidence of leading chemists is quoted to show that the presence of other metals in small quantities—as iron, tin, zinc, arsenic, and the like—promotes the formation of insoluble scale on copper. Messrs. Pope and Cole attribute corrosion to the presence of silver, which is frequently met with in the copper of commerce.

The Author refers to his previous observations, showing that annealed steel is much more soluble in sea-water than tempered or hardened steel; and that, when they are in contact, the softer metal is rapidly corroded. He inclines to the opinion that the same difference holds true of copper of varying hardness; and that the copper beneath the spots of scale is softer than the surrounding copper, and makes the difference required for setting up the corrosive action. He assumes that an unsound cake of copper is taken for rolling which contains cavities or air-cells, such as are occasionally produced. When this is rolled into a bar, the cavities are extended in the direction of the length of the bar. When the pieces of bar are afterwards rolled into sheets, the cavities would also be extended in the direction of the width of the sheet. The changes of form would of course be irregular, and would tend to produce such shapes as were seen on the copper. The cavities would contain gas; and while copper is an excellent conductor of heat, gases are poor conductors. When the plates are heated and allowed to cool, the space at the cavity would be longer in cooling than the other parts; and, as a consequence, more scale would be formed at that place than elsewhere, and might adhere more firmly, or its formation might continue after the scaling process was considered complete. The layer of oxide and cushion of gas would prevent the copper at this point from becoming as hard, through rolling, as over the remainder of the surface. The fact that the copper appeared slightly laminated at some of the corroded spots seems to substantiate this theory. In conclusion, Mr. Munroe is of opinion that the corrosion of the "Juniata's" copper was due principally to the presence of spots of oxide of copper on the surface of the plates at the time they were put on.

D. K. C.

Italian Artillery.[1]

(Revue d'Artillerie, 1886, vol. xxvii. pp. 509–529.)

Coast-Guns.—The type originally in use was a short 9·45-inch cast-iron hooped and rifled B.L. gun; in order to improve its ballistic qualities it was lengthened and the short construction abandoned.

The sight carries three sets of graduations, one in millimetres, and the other two the ranges for shrapnel and shell. The sight is, like all other coast-guns, the naval pattern, consisting of two openings, one above the other, on a brass leaf, moved along a slide by means of a screw. The upper opening is divided at its centre by a vertical wire, which, by its intersection with the thin partition between the two openings, determines the line of sight.

A 12·6-inch cast-iron hooped and rifled B.L. gun was adopted in 1884. The principal dimensions and section of the gun are given. The total weight, with breech-piece and obturator, is about 37½ tons. The sight is similar to the 9·45-inch. This gun fires a common shell 2·4 calibres in length, and a piercing shell of 2·8 calibres.

The carriage and slide adopted, in 1883, is a modification of one made in 1877. A plan and elevation is given. The weight complete is about 20¼ tons. The carriage consists of two cheeks of 1-inch plate with an angle-iron frame. The cheeks are tied together by transoms, one in front, one under the trunnion, and two half transoms at the rear, hollowed out to allow of the necessary elevation of the gun. They are further held together by plates underneath and an angle-iron riveted to the centre transom and sides, which are also strengthened by angle-irons carried round the trunnion-bearings. The right-hand trunnion-cap has a slot in it to allow of the movement of a sight on the trunnion. A couple of foot-boards are fixed behind the half transoms, and form a platform for working from. A portion of these boards is made to hinge so as to allow of the passage of the shot-elevator, which is mounted on two screws, worked simultaneously; the shot is brought to a platform at the rear of the carriage-slide and pushed on to the elevator. A crane is also provided for loading, and can be used instead of the elevator. The carriage is held to the slide by four iron guides fixed to the inside faces of the cheeks, which are faced with bronze to reduce the friction on the slide. The elevating-gear is a double screw worked by bevel wheels from the right-hand side of the carriage, the gun rests on the head of the screw. The recoil is taken up by two hydraulic brakes with movable pistons; these have two grooves for the passage of liquid,

[1] Minutes of Proceedings Inst. C E., vol. lxxxvi. p. 473.

and working in them are two projecting pieces fixed in the cylinder with an increasing pitch.

The carriage-slide is of double T-iron girders fixed at an inclination of about 1 in 8. It is traversed on five cast-iron rollers, one in front, two in the middle, and two in the rear; the traversing-gear is connected with the middle rollers. The pivot is forward, but the front roller is in advance of it.

Under the heading of "very powerful guns," reference is made to the 100-ton Armstrong guns for the "Duilio," and other ships, and then a description of a second group of two different types is given. The first is a gun of 17·71-inch calibre, cast-iron, steel-hooped, firing charges of 485 lbs. with a piercing-shell of 2,204½ lbs. weight. This gun is the result of studies by General Rosset, and was made at Turin.

The second type is the 120-ton 15·74-inch Krupp gun ordered in 1885; four of these guns 35-calibres length are being made.[1]

The range tables for the 17·71-inch and 12·6-inch guns are constructed for 8,750 yards. The 9·45-inch tables go up to 9,850 yards.

Tables of the ballistic effects of these guns are given. At the longest ranges the fire of the 9·45-inch gun is effective against unarmoured vessels and the unprotected ends of ships.

The piercing-shell penetrates a thickness of iron plate equal to its own calibre, at a range of 1,093 yards; beyond 6,560 yards the angles of descent are considerable, and projectiles have good effect on armoured decks. Up to 8,750 yards the 12·6-inch shell is effective against the unarmoured ends of ships, and at 1,093 yards penetrates a little greater thickness than its own calibre; between 6,560 and 8,750 yards it is useful against armoured decks.

The 17·71-inch projectile penetrates a thickness of 1½ calibres at 1,093 yards, and at the higher ranges is destructive to armoured decks and turret-roofs.

Howitzers.—The 9·45-inch howitzer is of old date, a special masonry platform arranged to allow of angles of fire of 95, 105 or 120 degrees was sanctioned in 1885. Some experiments were made with this gun to test the effect of an explosive mixture of 12 lbs. of bi-nitro-benzole and nitric acid in a Gruson shell, prior to this a common shell was fired against a plated shelter so that the results might be comparative, but though similar effects were produced, the Gruson shell was less powerful. Two more common shells and three more Grusons were fired, the former penetrated the cover of the shelter formed of planks on which a cast-iron plate 3·93 inches thick was laid, the whole being covered with earth; the earth was removed for a diameter of 13 feet 4 inches, and to a depth of 40 inches, the plate being broken into large pieces, the planks were also broken and the timber supports damaged. The results with Gruson shells were not considered superior, and the trials were discontinued.

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[1] Now being delivered. (Note, November 1886.)

In 1881 the trials of an 11-inch B.L. cast-iron rifled howitzer were commenced, the equipment of gun, carriage, slide, and platform, and projectile is now determined and finally adopted.

The gun was designed to compete with a similar one by Krupp of the same calibre, but with a screw breech and steel obturator. The weights of the projectile varied from 441 to 551 lbs. The range was 8,750 yards. The length of bore 92·4 inches or 8·4 calibres. Two howitzers were made with the object of experimenting with different natures of rifling, the first had a uniform pitch of 30 calibres, the depth of the grooves, sixty-four in number, being 0·068 inch. The second gun was like the first in every respect, except the rifling, which was an increasing pitch from nil to 20 calibres, and the area of the chamber was reduced. Both guns had steel tubes with two rows of steel hoops 2·4 and 2·75 inches thick respectively.

The projectile of 476 lbs. had copper guiding- and driving-bands, the latter 1 inch wide, its maximum diameter equal to the maximum diameter of the bore at the bottom of the grooves; this was afterwards altered, the width being increased to 1·18 inch, and the diameter reduced, except for a very narrow portion to ensure the filling up of the grooves. The projectile was deficient in stability during flight, and thus the effects of penetration and action of fuzes were irregular.

An automatic arrangement, fitted to the carriage and intended to act during recoil to bring the gun to the loading position and the projectile for the next round to the level of the breech, was abandoned, being a cause of more delay than help, partly owing to defective construction.

The angles of elevation allowed by the carriage were from ÷ 6 to + 65 degrees. It has a centre pivot, the blow on which was found to be very severe, amounting to more than 6 tons. This necessitated a special elastic platform, from which 1,225 rounds have been fired without any injury. Range-tables have not yet been prepared.

A 44-lb. charge of progressive large-grain powder with the first gun gave a range of 8,750 yards at 45° elevation, the pressure being 13·3 tons. This was considered too high for service use, and was fixed as a maximum which it was unwise to exceed. With a smaller grain powder, up to 6,560 yards greater precision was obtained within the above limits of pressure, so for general use the smaller grain powder has been adopted, the larger being reserved for ranges above 6,560 yards. An increased velocity of 60 feet being obtained from the second gun with reduced chamber, the chamber of the first was reduced to the same cubic capacity by inserting a copper ring; but as this gun showed a defect near the obturator the liner was removed to give more air-space for the charge and reduce the pressure. This howitzer was made from a tube rejected for a gun, but by shortening it the cause of rejection was cut away. The best results were obtained from the uniform pitch of rifling even with low charges.

The article describes and illustrates the arrangement of a 2·75-inch bronze gun, fitted in the chamber of the large guns with suitable centering-plates, so that the drill may take place with economy of ammunition; by this means all the drill-operations can be gone through with the heavy gun and the practice made from the small gun inside. The small gun is closed by a De Bange obturator fitted to the breech-block of the large gun. By having different obturator-stems and centering-plates for the various sizes of guns, the small gun can be used with a large number.

At the end of the article is a complete Table of particulars of the various guns in service.

J. H. R. W.

On the Measurement of the Power absorbed by Apparatus for Alternating-Currents. By E. Hospitalier.

(L'Electricien, 1886, p. 561.)

The power absorbed in any electrical apparatus is usually determined by the product of the difference of potential between its terminals into the intensity of the current, but this is true only for a continuous current, the variation of which is practically nil. It is quite different for periodically changing, and particularly for alternating, currents, when there is any self-induction in the circuit. In these cases the intensity of the current will not at each instant be the same as the ratio of electromotive force to resistance, but there will be a difference in phase between the curves representing those quantities, which may vary from 0°, in the case of a simple circuit of incandescent lights, up to a theoretical 90°, in which latter the work absorbed would be zero, while the indications of the instruments recording the intensity and electromotive force of the current would remain unaltered.

Diagrams are given to exhibit the effect of particular differences in phase, as well as the electrical work, as a function of this phase. The calculation of this difference for any actual cases is one of difficulty, depending as it does on several conditions of the generator and the circuit, and can only be determined by experiment on any given circuit under the actual conditions of its working. Thus, for a difference of phase of only 30°, the difference between the actual work expended and that deduced from the indications of the instruments, may be as much as 15 per cent. This effect will enter especially into the calculations of the power and efficiency of transformers, and all such apparatus fed by alternating currents.

F. J.

On the Specific Inductive Capacities of certain Dielectrics.

By Adrien Palaz.

(La Lumière Électrique, vol. xxi., 1886, p. 97.)

The results and methods of previous experimentalists are first briefly mentioned with the conclusion that the want of agreement between them is beyond the limit of mere observational errors, and may be ascribed principally to the variation in the time of electrification, and to some effect introduced by the specific resistance of the materials in question. Maxwell's relation between the specific inductive capacity and the refractive index for any dielectric has been proved to maintain, for nearly all liquids with the exception of certain vegetable oils, the Author's researches having been directed to this part of the subject as well as to the question whether electro-magnetic force has any action on this dielectric quantity. The method adopted for comparing the capacities is that termed De Sauty's or the simple Wheatstone's bridge, in which two of the branch resistances are replaced by the condensers, the capacity of which is the object of comparison; the source of the current was furnished by the intermittent current of an induction-coil, and a telephone served for detecting the position of equilibrium. Attention is drawn to the fact that in order to obtain perfect silence in the telephone, not only must the conditions of equilibrium between the branch resistances and the capacities of the condensers be satisfied, but also the dielectric resistance of the latter must be infinite; this is well revealed by the impossibility of arriving at perfect silence in the telephone, and the minimum sound attainable in each case serves as an indication of the value of that specific resistance. It was necessary to form the resistance branches of incandescent lamps and adjustable wire rheostats, on account of the self-induction which was found to exist even in the double wound coils of the ordinary resistance boxes; the potential of the charging-current could be varied from 1 to 61 volts. The two condensers were formed each of two concentric cylinders of metal closed at one end and of such dimensions as to allow of an annular space, when placed one inside the other, of 1 millimetre ($\frac{1}{25}$ inch) in thickness, contact being prevented by small ebonite distance-pieces; of these, one served as an air-condenser, the other was filled with the liquid then under experiment.

The methods of procedure are described in full detail. Preliminary investigation showed that the variation of potential of the charging current was without influence on the comparison; that it was necessary, in order to avoid alteration due to the chemical action between the liquid and the walls of the containing-vessel, that the observations be carried out as soon as possible after the filling; and, that increase in temperature decreased the specific

inductive capacity to a greater extent than could be ascribed to secondary causes. The following Table exhibits the results obtained with an electrification of about $\frac{1}{50}$ second; inspection of the different values confirms Maxwell's law as given above, with, however, the same exception of the vegetable oils.

Description of Liquids.	Temperature in Degrees Fahrenheit.	Specific Induction. Air = 1.	Index of Refraction for the D line.	Temperature in Degrees Fahrenheit.
Petroleum, ordinary No. 1 . .	61·2	2·1234	1·4487	78·0
" " No. 2 . .	59·8	2·0897	1·4477	78·3
" rectified	64·0	2·1950	1·4766	79·2
Toluol, No. 1	64·0	2·3646	1·4949	71·5
" No. 2	63·0	2·3649	1·4948	72·2
Benzole	63·0	2·3377	1·4997	71·7
Bisulphide of carbon . . .	60·3	2·6091	1·6269	71·0
Rape-seed oil	69·8	3·027	1·4706	76·7
Castor oil	69·6	4·610	1·4772	76·4

The experiments on plate-condensers of paraffin, ebonite, resin and sulphur when placed in an intense magnetic field decisively proved that no change was thereby produced in their respective capacities, or at any rate none exceeding 0·07 per cent.

F. J.

Experiments on the Electric Conductivity of Gases and Vapours.

By Jean Luvini.

(Comptes rendus de l'Académie des Sciences, vol. ciii., 1886, p. 495.)

The Author experimented on air saturated with water-vapour at various temperatures between 16° and 100° Centigrade (61° to 212° Fahrenheit), the vapours of sal ammoniac, air heated by the flame of a candle, the smoke of an extinguished candle, and other gases and vapours, and found at all pressures and temperatures that they acted as perfect insulators, and that they cannot be electrified by friction either amongst themselves, or with solid or liquid bodies. In conclusion he remarks that all theories must be rejected relating to the electricity of machines, of air or clouds, in which it is assumed that moist air is a conductor, or that gases and vapours may be electrified by friction.

E. F. B.

Iron and its Compounds rendered Unoxydizable by the Electric Current. By A. DE MERITENS.

(L'Éléctricien, vol. x., 1886, p. 485.)

The recipes for effecting the so-called "bronzing" of iron or steel are most numerous, depending in their action on the formation of a layer of magnetic oxide ($Fe_3 O_4$) on the surface of the object, the result being, however, rarely satisfactory. By means of the electric current, on the other hand, the operation is carried out to perfection; the objects are placed to form the anode in a bath of ordinary or distilled water, maintained at a temperature of 70° to 80° Centigrade (158° to 176° Fahrenheit), the cathode being formed of copper, iron, or carbon; the current must be of sufficient intensity to decompose the water, and be regulated as in ordinary electro deposition to render the layer adherent and uniform. After one or two hours the layer of magnetic oxide will be found firm, and capable of receiving a brilliant polish. That the action of the current penetrates to some depth can be proved by grinding off the blackened surface thus formed, and placing it again in the bath, when the colour will be found to return, immediately on application of the current. If an article covered with a thick layer of rust (sesquioxide of iron) be subjected to this treatment the outer layers will be non-adherent, but lower layers will increase in firmness until the interior will be found quite perfect. The above process is the treatment applied to steel; for iron, however, whether wrought, malleable, or cast, to obtain an adherent film the water must be distilled, and the process modified as follows: the objects, after forming the negative pole of the bath, must subsequently be submitted to the action of the current at the positive pole, when the oxide will be reduced and the pores of the metal charged with occluded hydrogen; if now they once more form the anode, the result will not fail to give satisfaction. The ordinary methods, requiring eight to ten days, and applicable to steel alone, at their best leave much to be desired; whereas, by this electrical process, a few hours suffices for the development of most excellent results on articles of either iron or steel.

F. J.

On the Coefficient of Self-induction of the Gramme Dynamo. By — LEDEBOER.

(Comptes rendus de l'Académie des Sciences, vol. cii., 1886, p. 1549.)

Measurements were made with the object of discovering whether in these machines the magnetic field and the extra current were proportional. The results are plotted, and the diagrams show so perfect an agreement, that the variations of the extra current permit those of the magnetic field brought about by the inductors to be anticipated. On comparing these curves with the "cha-

racteristic" of the machine, it was found that there was no proportionality between the ordinates of these two curves, and that for high intensities the electromotive force falls much more rapidly than the intensity of the magnetic field; the inductors were not saturated at 18 amperes, nor even at 30. In another series of experiments the coefficient of self-induction of the ring was determined, which was found to diminish by a half when the inductors were strongly excited; the extra current was represented by a straight line, proving the coefficient of self-induction to be independent of the current in the ring, contrary to what usually happens in bobbins with iron cores. Theory indicates that if the magnetization of the core is not influenced by the current circulating in the coil, the result should be the same as if there were no iron core. To test this the following experiment was made. In an apparatus consisting of two concentric coils and a movable iron core, the coefficient of self-induction of the outer coil was measured by means of a very weak current, the iron being removed and found to be 0·107; with the iron core replaced it measured 0·403. The last experiment was repeated with a powerful continuous current in the exterior coil, when the coefficient was found to be 0·110. In these conditions the effect of the current was to neutralize that of the iron core.

E. F. B.

On Magnetization. By Professor Mascart.

(Journal de Physique, 1886, p. 293.)

In obtaining coefficients of magnetization, these have always been found higher when experimenting with closed rings than with cylinders; the question arises whether one of the methods is liable to error, whether in rings, for instance, a special phenomenon exaggerates the effects of induction. To settle this question the Author employed, with the same iron wire, closed rings and a series of cylindrical rods in which the ratio of the length to the diameter varied between very large limits. With the iron employed, when the ratio of the length to the diameter varied from 40 to 500 or 600, the maximum value of the coefficients varied from 25 to 190 or 40 to 220, while the corresponding magnetic fields diminished from 20 to 25 C.G.S. units to 3; the same wires employed in the form of rings gave corresponding results. The two methods were therefore found equivalent when the length was at least 500 times the diameter.

As regards short cylinders, the Author found that as the ratio of the length to the diameter diminished, the mean coefficient of longitudinal magnetization diminished very rapidly, and eventually became equivalent to the transverse. The coefficients were more nearly equal when soft steel was used, and much more so with tempered steel.

E. F. B.

The Influence of Temperature on Magnetization. By — Berson.

(Annales de Chimie et de Physique, 1886, p. 433.)

A bar of magnetizable metal, of constant temper, being raised to different temperatures in the same magnetic field, it was sought to determine in the first place the total magnetization in each case, and then the permanent magnetism which remained, as soon as the magnetizing force was removed. From this the temporary magnetism was obtained by subtraction.

The subject is treated in two parts, the first refers only to the variations of the magnetic moment of the same bar, the second to the variations in quantity and distribution of the magnetism. Experiments were made on iron, nickel, cobalt, and steel. The Author employed Gauss's method, which consists in measuring the deviation produced on a magnetized needle by a bar-magnet, which is placed horizontally in a plane perpendicular to the magnetic meridian, passing through the centre of the magnetic needle; the tangent of the deviation, or if this is small, the deviation itself is proportional to the magnetic moment of the bar-magnet.

The apparatus employed comprised a battery giving a constant current regulated by means of a rheostat and galvanometer, a cage containing the magnetic-needle whose deviations had to be registered, and a coil to receive the bar to be experimented upon, plunged into a bath whose temperature could be determined. In each experiment, the temperature of the bath was maintained almost stationary; the current was formed and regulated by means of the rheostat, it was then interrupted and passed for a short time in the opposite direction. During this time the thermometer rose two or three degrees, and then again became stationary. The battery-circuit being closed, three consecutive readings were taken; it was then broken and three more readings taken. The current was then formed in the opposite direction, three readings were taken, and three further readings after the current had been taken off. These twelve readings were made in about half a minute, and the temperature did not vary as a rule by more than one degree.

Iron.—As the result of his experiments, the Author found that the total magnetism was sensibly independent of the temperature between the limits of 32° and 342° Centigrade (90° and 648° Fahrenheit). It appeared to increase very slightly with the temperature, and to give a maximum at about 300° Centigrade (572° Fahrenheit). As regards the residual or permanent magnetism, the variations were found to be so slight that the Author thinks them due to errors of observation.

Nickel.—As the result of his tabulated experiments, the Author found that the total magnetic moment of a cylindrical bar of nickel increased with the temperature up to about 200° Centigrade

(392° Fahrenheit), and then diminished; from 290° Centigrade (454° Fahrenheit) the fall became very rapid, so that at about 340° Centigrade (644° Fahrenheit) it was nil.

The residual magnetism diminished constantly with increase of temperature, becoming nil at about the same temperature as the total magnetic moment. The temporary magnetic moment increased, and became a maximum towards 250° or 260° Centigrade (482° or 500° Fahrenheit), and then vanished.

Cobalt.—The total magnetic moments, permanent and temporary, of a bar of cobalt, constantly increased with the temperature up to 320° Centigrade (608° Fahrenheit), at which they were two and a-half times as great as at ordinary temperatures.

Tempered Steel.—The total and temporary magnetic moments of a bar of tempered steel, increased constantly with the temperature up to 335° Centigrade (635° Fahrenheit), and this increase amounted to 14 per cent. of the initial quantity, for the total magnetization, and 21 per cent. for the temporary. The residual magnetic moment of tempered steel constantly diminished with increase of temperature, and was found to fall as low as 76 per cent. of the initial amount. Besides this the magnetism of a bar of steel in a given magnetic field was found to be a function not only of the final temperature, but of the variation of the temperature whilst the force of the magnetic field was in action; and if magnetized at a certain temperature the magnetic moment diminished, both with rise and fall of temperature.

To study the influence of temperature on the distribution of the magnetism in a cylindrical bar, the Author used similar apparatus to that previously employed, the temperatures being those of melting ice, boiling water boiling naphthalene (216° Centigrade, 421° Fahrenheit), and boiling paraffin (340° Centigrade, 644° Fahrenheit).

Iron.—Between the temperatures of 23° Centigrade and 327° Centigrade (74° to 621° Fahrenheit), the magnetization of iron was found to be independent of the temperature both as regards its quantity and distribution, which results agree with those of former experimentalists.

Nickel.—Two distinct series of experiments were made, the one on bars, and the other on thin and long needles. In the first series, the temporary magnetism was found to change with the temperature, accumulating on the terminal faces; it increased with the temperature, becoming at 216° Centigrade (421° Fahrenheit) double what it was at 0° Centigrade (32° Fahrenheit). In the second series, the quantity of magnetism was found to increase up to 260° Centigrade (500° Fahrenheit), becoming nothing at 340° Centigrade (644° Fahrenheit). The fraction of this quantity distributed laterally increased in the first place, but began to diminish at 250° Centigrade (482° Fahrenheit). The magnetization of the bars increased towards 290° Centigrade (454° Fahrenheit), from which it fell quickly. In the case of temporary as of permanent magnetism, magnetic influence was only found at

a certain distance from the middle of the needle, the distance appearing to be independent of the temperature.

Cobalt.—As the temperature increased the magnetism increased in quantity, and was driven to the ends of the bar, the terminal plane faces becoming more and more magnetized, as regards total, temporary, and residual magnetism.

Tempered Steel.—Between the temperatures of 25° Centigrade and 100° Centigrade (77° to 212° Fahrenheit), there was found to be little difference, beyond a slight diminution of the magnetism of the ends of the bar. Above 100° Centigrade (212° Fahrenheit), the distribution was modified in a more marked manner, and the quantities of magnetism diminished more rapidly. As regards steel, nickel, and cobalt, there appears to be no simple relation between the distribution of temporary and residual magnetism at the same temperature. What may be called the parameter of distribution, as well of quantity, are not generally found to vary in the same way for the two different magnetisms with change of temperature.

As a check on the magnetic moments directly observed by means of Gauss's method, the Author calculated them from their known distribution by means of Biot's formula, and found a close agreement between the numbers obtained by the two methods.

The work was carried out in the physical laboratory of the Collège de France, and the Author desires specially to thank Professor Mascart for the facilities he rendered in its prosecution.

E. F. B.

On the Specific Induction of Magnets in Magnetic Fields of Different Intensity. By Dr. Hilmar Sack.

(Centralblatt für Elecktrotechnik, 1886, p. 487.)

The specific induction of a magnet is the increase or decrease of the magnetic moment of the unit of mass by the unit of magnetizing or demagnetizing force respectively. The Author's experiments were conducted on a hardened steel bar, which had been strongly magnetized and subsequently treated for a long time in boiling water or steam, by placing it in a solenoidal coil, through which could be passed a current of given intensity either positive or negative in sign. The results are that, for magnetic fields of an intensity not exceeding six times that of the earth's horizontal component, the value for increasing and decreasing force is the same; this also holds good for fields up to seventeen times the earth's horizontal component, if the bar be first subjected to a series of reversals of the current, for the first application of the current gives a larger value than subsequent ones. No permanent alteration in the moment of the bar can be positively detected until the magnetic field is twenty times as strong as the earth's horizontal component.

F. J.

On the Magnetizing Curve for Different Sorts of Iron and Steel, and a means of Determining their Hardness thereby.

By Karl Zickler.

(Centralblatt für Elecktrotechnik, 1886, p. 522.)

From an extensive series of experiments on different makes of steel the results obtained are plotted in diagrammatic form with the ampere-convolutions as abscissas (x) and the magnetic moment as ordinates (y). The curve for any given bar may be divided into three portions, the first commencing at the origin being convex to the axis of x, the next part being a straight line, and the last concave to the axis of x. The straight line represents the well-known equation for magnetizing force $y = a\,x + b$, a and b being constants depending on the material. The point where the straight line would cross the axis of x is further removed from the origin as the material increases in hardness, or, in other words, the quotient $\frac{b}{a}$ of the above formula is a relative measure of the hardness of the different sorts of iron and steel; thus steel treated by the Clemandot compression process is found to be 22 per cent. harder than before treatment. The concave portion of the curve is nearer to the axis of x the greater the proportion of carbon in the material. The above results are deduced from observations on bars of the same length and weight. For bars of the same length but of different weight from a given material, the quantity b remains constant, or the straight lines cut the axis of y at one and the same point; the quantity a is inversely proportional to the fourth root of the weight of the bar, or square root of its diameter. The form of the cross section of the prismatic bar does not affect the quantities a and b, if the weight and length remain unaltered.

F. J.

Electric Installation at Thorenberg, near Lucerne.

(Schweizerische Bauzeitung, 1886, p. 67.)

At Thorenberg, about 3 miles from Lucerne, a considerable water-power, formerly used for driving the machinery of some ironworks no longer existing, has been utilized for driving dynamos, the currents from which are employed partly in working a mill 3 kilometres distant, belonging to Messrs. Troller Brothers, of Lucerne, and partly for the electric illumination of the Hotel Schweizerhoff and the visitors' quarter in Lucerne. There is an available fall of 10 metres (32·809 feet), developing 250 HP., and driving a turbine of the Girard type. The turbine

is regulated by an automatic governor, said to be capable, with a difference of only 2 per cent. in the velocity, of neutralizing inequalities of 100 HP. in the work required. For the transmission of power two continuous-current machines (on the Thury system) are employed as generators, and two similar machines, of the same diameter, but 10 centimetres (3·94 inches) shorter, as motors at the mill. These machines have three pairs of field-magnets, with compound winding. The armature, of the drum type, is wound with wire of rectangular section; the core consists of an iron drum, wound with iron wire (Mordey system). The weight of a 50 HP. dynamo of this type is 2,500 kilograms (5,511·5 lbs.). The normal electromotive force of the two generators arranged in series, at 400 revolutions per minute, is 1,100 volts; together they absorb 100 HP. The conductors are calculated for a current of 60 amperes. The ordinary speed of the electromotors is 350 revolutions per minute, and the power given out to the mill is said to be 60 per cent. of that absorbed by the dynamos.

For the electric lighting, at present two alternating current dynamos are employed, constructed on a system similar to that of Lontin, manufactured by Messrs. Ganz and Co., of Buda-Pesth. They are capable of producing an electromotive force up to 1,900 volts, and develop each 75,000 watts; the ordinary speed is 250 revolutions per minute. They differ from other alternate current machines in being self-exciting. This is effected by making two of the stationary coils act as complete inductors with secondary coils. The secondary circuit passes through a so-called compensator to the commutator on the front side of the machine, where the alternating current becomes continuous, and is conducted through the hollow shaft and connected with the closed circuit of the revolving electro-magnets. By means of the compensator the high tension in the secondary circuit is transformed into low tension; it also regulates automatically the current in the magnet-coils according to requirements. An interesting feature of the installation are the Zipernowski-Déri transformers, by means of which the currents of high tension and small quantity from the dynamos are transformed into currents of low tension and great quantity before distribution to the lamps. The principle of the Zipernowski transformer is a kind of inversion of that of the well-known induction-coil. At present there are at the Schweizerhof 1,400 Swan lamps and two arc-lamps, served by the described arrangement, and the results so far have been very satisfactory.

The original is accompanied by several illustrations.

G. R. B.

On the experiments of Mr. Marcel Deprez relative to the Transmission of Energy between Creil and Paris. By — Lévy.

(Comptes rendus de l'Académie de Science, vol. ciii., 1886, p. 314.)

A commission was appointed at the request of Messrs. Rothschild, consisting partly of members of the Academy, and partly of Engineers, to report on the results obtained by Mr. Marcel Deprez[1] in his experiments on the transmission of energy between Creil and Paris, who appointed a sub-commission, of which Mr. Lévy was reporter, to prepare a report. The object of the experiments was to transmit electrically 200 HP. from Creil to Paris, a distance of 56 kilometres (35 miles), with an efficiency of 50 per cent. The motive-power was to have been supplied by two locomotives, transmitted by means of a single generating dynamo, working two motors in Paris; one of these only was made, so that only 50 HP. were received at Paris of 100 supplied at Creil. The experiments were not in the first instance successful, owing to an imperfect construction of the generating machine. In the ordinary Gramme dynamo, the soft iron core is made of iron wire, Mr. Deprez adopted rings of thin sheet iron, insulated by means of paraffined paper; this was properly accomplished, but the bolts which held the whole together were only covered with shellac, which was fractured by the pressure; thus, owing to faulty construction, Foucault currents were produced, and the results were almost nil. The ordinary core of iron wire was next employed, but the wire was not sufficiently insulated, so that a squall having mixed the line and telegraph wires, discharges took place, which resulted in the rings being rendered unfit for use, and the experiments had to be interrupted. After this, Mr. Deprez determined on carrying out his original arrangement, modified by building up the machine in sections, so that any portion injured could be speedily renewed. The new rings have worked in a satisfactory manner since February, running from six to eight hours a day, without damage, and heating only about 47° Centigrade (117° Fahrenheit). The inductors of the generating-machine comprised eight horse-shoe magnets placed in the planes, passing through the axis of the rings, two and two diametrically opposed, so that their polar extensions embraced the circumferences of the rings. By the employment of two rings with horse-shoe magnets consequent poles were avoided. The motor-dynamo was similar to the driving, only smaller, the cores of its rings being of soft iron wire. The leading wire was 112 kilometres (70 miles) long, of bronze, 5 millimetres ($\frac{1}{5}$-inch) in diameter, with a resistance of 97·45 ohms. It was well insulated where connected with the machines, and placed at a great height above the ground, at a distance of a metre (3·28 feet) from telegraphic and telephonic wires, the distance being found

[1] Minutes of Proceedings Inst. C.E. vol. lxxxiii. p. 534.

sufficient where a return wire is used as in the present case. Both the dynamos were excited by Gramme machines, having currents of low tension. There were thus three distinct electric circuits. A local circuit at Creil, formed of the exciter and the inductor of the generating machine, which produced the magnetic field there, a similar local circuit at La Chapelle for the motor or receiving machine, and a general circuit which included the line wire and the rings of the generating and motor dynamos, the latter alone being of high tension. A starting commutator was arranged at La Chapelle, which placed the local circuit there in the line circuit, so that the current entering the rings and inductors of the receivers, the former were put in motion; their movement was communicated to the exciter mechanically; the magnetic field at La Chapelle increased until it attained its normal, when the same commutator disconnected the local from the line circuit; thus the magnetization was started in the first instance by means of the current of high tension, and afterwards kept up by that of the exciter. The larger portion of the force was employed to work the pumps of accumulators, and the balance to drive small machines.

The commission draws attention to the perfect regularity of the movement of the machines, and the complete absence of sparks, notwithstanding the high tension of the current and the size of the machines. This was due to the great power of the magnetic field, and the excellent proportion between the current of the rings and that of the inductors. There was very little heating after several hours' work, the number of revolutions per minute being from 200 to 220. Since February 1886, electrical and mechanical measurements have been taken daily. The sub-committee after testing the galvanometers and dynamometers took observations which agreed with those daily recorded within the limits of errors of observation. They then proceeded to measure the quantity of work transmitted. The generating-machine made from 168 to 218 revolutions per minute, its electromotive force varying from 4,887 to 6,290 volts; of 67 to 116 HP. employed at Creil, 27 to 52 were utilized at Paris. The efficiency was found to increase with the energy transmitted, the maximum being 45 per cent. Of the 116 HP. 35·6 were taken up by the generating-machine, 7·3 by the line, and 21·0 by the motor, as measured electrically, whilst according to the mechanical measurements they amounted to 32·2 HP. and 19·1 HP. for the generator and motor respectively, the loss on the line obtained by difference being 12·7 HP.

The Committee next entered upon an examination of the industrial value of the Creil machine, as regarded the inductors and rings, and the efficiency and mechanical qualities of the machines. These last were evidently the facility of construction and repair of the machine, its massive dimensions and the ease with which it worked; as regards the magnetic field, the tabulated experiments showed that the generating machine at Creil supplied a magnetic field of 1,900 C.G.S. units, having a volume of 111 cubic decimeters (3·9 cubic feet), with an expenditure of

12·68 HP.; the weight of copper being 2,534 kilograms (5,575 pounds). As regards the rings, these are the more perfect the less work there is absorbed by Foucault currents in the iron cores, and by the phenomena of self-induction produced twice for each section of the ring. The work supplied to the generating-machine amounted to 116 HP., the electromotive force of the Creil machine was 6,290 volts. At a velocity of 218 revolutions per minute, the work absorbed by friction with the circuit open was 9·85 HP., and by the exciter with a current of 36 amperes, 12·68 HP., so that the efficiency, or coefficient of transformation was 0·9. The commercial efficiency of the Creil machine was about 72 per cent., the mechanical losses due to friction, vibration, &c., amounting to 8·5 per cent., the force expended in producing the magnetic field to 11 per cent., and the heating of the ring to 8·5 per cent.; the efficiency of the machine at La Chapelle was 76·5 per cent., and that of the two machines connected, 55 per cent., there being a further loss due to the resistance of the line of 10 per cent. Owing to the energy absorbed by the dynamometers, measuring instruments and apparatus, the actual commercial efficiency may be considered to be 50 per cent. The running of the machines was in every way satisfactory, the generating-machine making 216, and the motor 295 revolutions per minute. The tension was very high, being 6,290 volts, but hitherto no accidents had resulted. As regards cost, the total amounts to £5,000, the generating-machine being £2,000, the motor £1,200 and the line £1,800.

From a scientific point of view these experiments appear to show that the effects of self-induction were got rid of altogether, or almost altogether; they show also that with careful construction Foucault currents can be removed in the largest machines; besides this they confirm the laws of electro-dynamic induction far beyond the limits which could be attained in previous experiments.

The Commission complete their report by complimenting Mr. Marcel Deprez on the results he had obtained, and thanking Messrs. Rothschild for the liberality with which they supplied the means of carrying on the experiment.

E. F. B.

An Electric Buoy.

(L'Electricité, 25 September, 1886.)

Trials have been made at Asnières of a new buoy lighted by electricity, fitted to render service in saving life by night at sea. It is the invention of Mr. Depetasse. The buoy, large size, weighs 38 kilograms (83·8 lbs.). It carries, below the line of flotation, six Gadot accumulators, furnishing an illuminating power of six candles to a glow-lamp placed 1 metre above the water. The light, which is visible up to a distance of three miles, lasts for at least six hours.

The buoy being placed behind a ship, the man on watch, as soon as he hears the cry "man overboard," cuts the rope by the stroke of an axe, and this severance, displacing an iron pin, the current is established automatically. The experiments demonstrated the practical utility of this life-saving apparatus.

A. B.

The Employment of Spiral Springs for Measuring-Instruments, and the Accuracy of Galvanometers constructed therewith.

By W. Kohlrausch.

(Electrotechnische Zeitschrift, 1886, p. 323.)

The causes which are likely to affect the constancy of spiral springs are mentioned in detail by the Author, with an account of experiments bearing on each point, in order to afford some idea of the reliance that can be placed on the indications of instruments into the construction of which they enter. The effect of age, judging by observations on a brass spring extending over a period of seven years, may be completely neglected. Continuous and prolonged deformation produces a small amount of permanent set, so that the spring when released does not return to the original position, but does not actually alter the indications of the instrument if the readings are taken from the new zero thus found; steel is in this case less affected than German silver. Oft-repeated, but intermittent deformation—as exhibited by a spring of 90 convolutions and 2½ inches long being stretched so as to change from a length of 3½ inches to 9 inches, two hundred times per minute for four hundred minutes—introduced no appreciable alteration in its subsequent indications. An increase of temperature of 18° Fahrenheit raised the indications of a Siemens torsion-galvanometer about $\frac{1}{10}$ per cent.; so that the reduction in the elasticity of the spring is apparently almost equal to the decrease in the moment of the magnet, which would be, under these conditions, about 0·4 per cent. Further experiments on loaded springs confirmed this conclusion, and showed that steel was again to be preferred to German silver. By combining the results given above, the utmost limit of error introduced by the use of spiral springs cannot exceed 0·5 per cent. If however, as is the case in the Siemens tension-galvanometer, the current passes through the spiral spring, care must be taken that the heating from the passage of the current is not excessive. The Author found an alteration of 1·4 per cent. in the indication of such an instrument after thirty minutes' continuous test, with a difference of potential of 100 volts between the terminals. If such instruments be calibrated at intervals to correct the decrease in the moment of the magnet, an accuracy within about 0·1 per cent. can be relied on. With the Siemens dynamometer for intense currents, the limit of

error, owing to the friction at the mercury contacts, is about 1 per cent. Another form of instrument, the spring-galvanometer of F. Kohlrausch,[1] is also reliable within 1 per cent., and is perfectly aperiodic with frictionless damping. Owing, however, to the employment of an iron core, the readings of currents taken in ascending and descending order of magnitudes will vary to some considerable percentage from the effect of residual magnetism, which exists in even the best soft iron, if this error be not eliminated by mechanically bringing the core past the position it would take up under the action of the current, and then leaving it free to return to that position.

F. J.

On the Measurement of very High Pressure and of the Compression of Liquids. By E. H. Amagat.

(Comptes Rendus de l'Académie des Sciences, vol. ciii., 1886, p. 429.)

The Author experimented on water and ether at zero Centigrade and at two neighbouring temperatures. As regards variation with pressure, the coefficient is found to diminish as the pressure increases, throughout the whole range of pressures. At 3,000 atmospheres, about 20 tons to the square inch, the volume of water was found to be reduced by one-tenth, and its coefficient of compression by one-half. The Author gives the following Tables in which the numbers represent apparent coefficients, and promises to supply later the value of the coefficient of compression and expansion of certain liquids throughout the whole scale up to 3,000 atmospheres.

Water at 17·6 C. (63·6° Fahrenheit).		Ether at 17·4 C. (63·2° Fahrenheit).	
Pressures in atmospheres.	Coefficients of compression.	Pressures in atmospheres.	Coefficients of compression.
From 1 to 262.	0·0000429	From 1 to 154.	0·000156
„ 262 „ 805.	0·0000379	„ 154 „ 487.	0·000107
„ 805 „ 1,334.	0·0000332	„ 487 „ 870.	0·000083
„ 1,334 „ 1,784.	0·0000302	„ 870 „ 1,243.	0·000063
„ 1,784 „ 2,202.	0·0000276	„ 1,243 „ 1,623.	0·000051
„ 2,202 „ 2,590.	0·0000257	„ 1,623 „ 2,002.	0·000045
„ 2,590 „ 2,981.	0·0000238	..	..

E. F. B.

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[1] Electrotechnische Zeitschrift, 1884, p. 18.

Dynamometer with Optical Measuring-Apparatus.

By P. Curie.

(Comptes rendus de l'Académie des Sciences, vol. ciii., 1886, p. 45.)

The apparatus consists of a horizontal shaft supported in two bushes. Two pulleys at the extremities of the shaft serve to transmit the motion of the motor to the receiver. The work is measured by the torsion of the shaft between the two pulleys. The shaft has an internal passage of 8 millimetres (0·315 inch) diameter. The extremities are closed by two thin plates of quartz cut parallel to the optical axis, and each giving a difference of half a wave between the ordinary and extraordinary rays. A polarized ray of monochromatic light traverses the axis of the shaft, and the two plates of quartz cause the plane of polarization to turn by a small quantity so long as there is no torsion; but if there is a certain torsion, the plane of polarization of the emerging ray will be double this, and hence the moment of the force of torsion will be known from the weight determined directly which is required to produce a rotation of 1°. The sensitiveness of the apparatus depends on the diameter of the pulleys, and hence the same instrument will serve to determine very different powers if supplied with pulleys of different diameters.

The apparatus will serve equally as an absorption-brake; it is only requisite to employ the work transmitted to produce friction, of which the amount may be varied at will.

E. F. B.

On an Aerostatic machine proposed by General Meusnier.

By — Létonné.

(Comptes rendus de l'Académie des Sciences, vol. ciii., 1886, p. 237.)

With this memoir was presented a photographic reproduction of an album containing sixteen plates of drawings which General Meusnier prepared from 1784 to 1789, and eight tables giving coefficients of resistance of various materials suitable for the construction of his aerostatic machine. In his memoirs on the subject, General Meusnier drew attention to the necessity of giving an elongated form to the balloon; that there should be an interior space into which air can be passed, and that revolving paddles, constituting true helices, should be employed. All these arrangements were carried out in the experiments made at Chalais during the last two years.

E. F. B.

On a Physiological Condition which Influences Photometric Measurements. By A. CHARPENTIER.

(Comptes rendus de l'Académie des Sciences, vol. ciii., 1886, p. 130.)

If there are two luminous sources of different colours, by a proper arrangement of their distance two luminous fields of equal intensity may be produced on the screen of the photometer; but the equality is only apparent, and depends upon the size of the fields, and the distance of the screen from the eye. As the distance is increased, the less refrangible colours appear relatively the most intense, and as it is diminished the colours near the violet end of the spectrum. These phenomena are most marked when the image on the retina is not larger than the *fovea centralis* (about $\frac{2}{10}$ millimetre—$\frac{1}{125}$ inch—in diameter).

E. F. B.

An Improved Artificial Horizon for Astronomical Observations. By Rear-Admiral MOUCHEZ.

(Cosmos, July 1886, p. 368.)

Owing to the vibrations of the soil it has hitherto been almost impossible to obtain altitude observations at the Paris Observatory, and various unsuccessful attempts have been made to overcome this difficulty. Mr. Gautier has at length succeeded in providing a perfect remedy. The new apparatus, which is shown in an illustration, consists of a couple of cylindrical vessels made of cast iron, resting one within the other, the lower one being slightly larger than the one above it. The mercury is placed in the lower vessel, and is allowed to enter the upper one through a small hole, about 4 or 5 millimetres (0·157, 0·197 inch) in diameter, which hole can be opened or closed by means of a milled head and screw situated at the side of the cylinder. In the centre of the base of the upper vessel there is a female screw which works on a screw firmly attached to the base of the lower vessel. By rotating the upper cylinder and opening the small hole in its base, some of the mercury on which it floats is forced in and forms a perfectly clear and stable mirror. To secure the best results the central screw must neither be too slack nor too tight, and the condition of semi-flotation of the vessel forming the bath, with the central screw attachment to the vessel containing the mercury, is found in practice to avoid entirely all earth tremors, while the arrangement described preserves the mercury in the lower vessel in a perfectly pure state when not in use.

G. R. R.

The Distance of Visibility of Ships' Side-Lights.

By M. Burstyn.

(Mittheilungen aus dem Gebiete des Seewesens, vol. xiv., 1886, p. 385.)

The minimum distance of visibility fixed by the international regulations for the green and red lights of sea-going vessels is 2 nautical miles, and, according to the Author's determinations, the minimum intensity of the source of light, which suffices with the lenses usually employed, and in a clear atmosphere, is for the red light between 3·7 and 4 standard candles, and for the green, 0·7 to 0·9.

If the absorption of light be assumed to vary directly as the thickness of the transmitting medium, then the distance at which a light is visible will vary as the cube-root of its intensity, or $d = a\,i^{\frac{1}{3}}$; and from the Author's experiments d will give, for a clear atmosphere, the distance in nautical miles if i is expressed in tenths of a standard candle as the unit, and a is given the values 1·2, 0·98, and 0·6 for the white, green, and red lights respectively. Further experiments as to the effect of foggy medium did not lead to any satisfactory results.

F. J.

On the Tension over Fluid and Solid Substances of their Saturated Vapours. By Wilhelm Fischer.

(Annalen der Physik und Chemie, vol. xxviii., 1886, p. 400.)

By application of the laws of the mechanical theory of heat, Kirchoff arrives at the conclusion that at the melting-point the curve exhibiting the tension of the saturated vapour will have a point of inflexion; and that for ice and water at 0° C. (32° F.) the difference between the differential coefficients at that point would be 0·044. The Author's experimental investigation is in full accord with the above theorem; thus for water and ice between 0° and − 9° C. (15·8° F.) the curves are not identical, the former lying above the latter, and both meeting at 0° Centigrade, where the vapour tension equals 4·63 millimetres (1·8 inch) of mercury, and the difference between the differential coefficients or tangents to the two curves is 0·0465. In the case of benzol in the fluid and solid state between 0° and 6° C. (42·8° F.), the curves are not only not identical, but do not meet at the solidifying point (5·3° Centigrade), where the tension over the fluid substance is 0·44 millimetres (0·17 inch) higher than that over the solid. As a conclusion from the above-mentioned results, the evaporation heat of ice must equal the sum of that for water plus the latent heat of ice at freezing-point. F. J.

On Solutions. By VLADIMIR ALEXJEFF.

(Annalen der Physik und Chemie, vol. xxviii., 1886, p. 305.)

The solutions resulting from the mixture of two liquids may be separated under two types, viz., the one containing those that develop no chemical action, the other containing those that form chemical compounds of greater or less stability.

The laws educed for the first type from the Author's extensive experimental research, are that the solubility increases regularly with the rise of temperature up to a certain point, when mixture takes place in all proportions of the two liquids; that the mutual solubility of the two fluids is different, the one with the greater cohesion being the more soluble; further, that the heat-effect which accompanies the process of solution is negative in sign, and the maximum obtains with equality in the proportions of the components. The heat-capacity of the mixture is equal to or greater than that of the mean of the two liquids. For those that come under the second type, it is found that the solubility does not increase regularly with rise of temperature, but there are inflexions in the representative curves, and no correspondence can be traced between cohesion and solubility. For a hydrate the solubility is always greater than for the anhydrous compound. The stability of a compound which is formed of an unequal number of molecules of the components, varies according as one or other of them is in excess; this difference results in the heat-effect being sometimes positive and sometimes negative, for the positive effect resulting from combination may be partially compensated or wholly reversed by the negative effect from the process of solution. The stability of the compound between any given limits of temperature depends on the existence of the previously-mentioned inflexions (maximum or minimum).

With respect to the influence of molecular aggregation, substances are more soluble when in the solid than when in the liquid state; at one and the same temperature the former allow of only one saturated solution, the latter, however, of two. Saturated solutions from the solid substance are formed at the saturation-temperature; but of the liquid, where the substance separates on cooling as a fluid, are formed at a higher temperature than the saturation-point. Isomeric solutions differ in their mode of formation as well as in the temperature at which separation occurs and the products thereof. For supersaturated solutions, there are two temperatures, one at which separation is possible, and the other at which it must absolutely take place. The temperature at which a solid substance melts in the presence of water is the "point of transition," by which is meant the change from the solution of the solid substance in water, into a solution of water in the self-same but molten substance. The analogous case of the existence of solid ice in water at 0° C., and of sub-cooled water or liquid ice

between that temperature and $-10°$ C. is instanced, and the solidification on introduction of a small particle of solid ice into the latter is ascribed to a sort of distillation between the two, resulting from the difference in their vapour-tensions.[1]

F. J.

Asbestos: a Monograph. By M. N. MELNIKOFF, Mining Engineer.

(Gorny Jurnal [Russian Mining Journal], 1886, p. 86.)

The Author treats of asbestos from historical, chemical, physical, and commercial points of view, and collects, in one comprehensive Paper a vast amount of information scattered through the literature of most of the European nations, and through many centuries of time.

Asbestos appears to have been known to the Jews of the time of Moses. It is described by Strabo; Dioskorides mentions its incombustible nature; the younger Pliny speaks of tissues made of a substance called asbestos which grows in India, that it was incombustible, and used as winding-sheets at the cremation of kings, to prevent their ashes being lost. He had seen napkins made of it, but it was so difficult to work that the price of the cloth was equal to that of pearls. Specimens of asbestos have been found in the ruins of Pompeii; they were enclosed in antique vases, and kept, probably, as curiosities. Marco Polo, travelling during the 13th century in central Asia, mentions a hill from which a substance of the nature of the salamander was obtained, for, when made into cloth, it could be thrown into the fire without receiving any injury. The process of manufacture he describes as follows:—The petrified substance, which looks like wool, is dried in the sun, then pounded in a copper vessel, water being added till all the earthy particles are washed away; it is then spun into thread, and finally woven into cloth, which is bleached by being exposed to fire for an hour. In the 15th century asbestos seems to have been largely employed for lamp wicks. About one hundred years ago the Swede, Foxe, proposed to cover the woodwork of houses with the "mineral cardboard," as it was called, as a protection against fire, and to sheathe ships, to guard them from marine boring-worms. Trials were made of both suggestions, but with no practical success. At the end of last century it was used in England mixed with tar, as a paint for ships. The credit of developing the properties of asbestos, and applying them to the arts, belongs to the present day. The material appears to have been known under at least twenty-two different names, among which the most prominent are Amianth, Indian cloth, Federweis, and feather alum.

Asbestos is a fibrous mineral, made up of extremely thin filaments, which have been proved to have a crystalline structure,

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[1] *Ante*, p. 575.

although the mass of the substance has none. The length of the fibres sometimes reaches several feet, but the usual length is between 1 and 3 inches, and they are sometimes found twisted up in entangled knots. The colour varies very much, but is most commonly white, brown, or pink, with a silky or fibrous lustre; hardness from 2 to 3; specific gravity from 2·57 to 3·71, subject to variation on account of its extremely hygroscopic nature.

The melting-point of asbestos varies considerably, the extreme limit being above 1,200° Centigrade (2,192° Fahrenheit). The thin fibres of many kinds can be melted in the flame of an ordinary candle. After heating to temperatures below its melting-point, it loses in weight and becomes more brittle.

The Author gives no less than twenty-two analyses of different kinds of asbestos, but the following composition he considers as typical: 58 per cent. of $Si\,O_2$, 28 per cent. of $Mg\,O$, and 13 per cent. of $C\,A\,O$; it is therefore a silicate of lime and magnesia, coloured by iron and manganese, and associated with a good deal of water, some of which can only be driven off at a red heat. It is now generally classed with the Augites and Hornblendes, and may be divided into two groups, asbestos with fibres laid parallel to each other, and asbestos with its fibres entangled or irregularly disposed. To the latter group belong the substances known as mountain leather and mountain cork, and to the former the varieties which are best capable of being worked into textile fabrics, and which are generally known as amianth.

Asbestos is chiefly found, in the form of veins, in metamorphic rocks; it is very widely distributed throughout the world, though the finer qualities and richer veins are by no means common. The usual thickness in Italy is from $2\frac{3}{4}$ inches to 8 inches, in Carolina and Virginia between $4\frac{3}{4}$ inches and 36 inches, in Canada about $1\frac{1}{2}$ inch. The length and depth of the veins are usually small, from 20 feet to 66 feet. The Author gives a long list of the localities in which the mineral is found, and discusses the various theories respecting its origin. Within the last ten years the use of asbestos in the arts has extended greatly. Its fibre has a strength ranging between that of flax and silk; it is a bad conductor of heat and electricity, it is insensible to the action of most acids, and to that of the caustic alkalis, and its specific weight is small. It seems certain that repeated heating to redness causes it to become brittle and lose much of its flexibility, probably on account of the loss of water of crystallization.

The preparation of asbestos yarn or cloth is rendered difficult on account of the ultimate fibres being perfectly smooth and free from the irregularities which characterize fibres of vegetable or animal origin.

The first process of manufacture is to sort the raw material into various classes. The pieces with long and parallel fibres are devoted to the manufacture of thread; the pieces with shorter fibre are used for conversion into felt or paper, and the refuse for working up into paint, fireproof linings, and so on.

The material intended to be made into thread is sometimes heated in a fire, and then quenched in water, in which it is steeped until it becomes considerably softer, but in some cases steeping only in warm water is sufficient. The fibres are separated by hand, and at the same time most of the extraneous earthy matters are washed out. This operation is also performed by machinery, by means of toothed rollers, between which the pieces of asbestos are passed. After washing, the fibre is carded by hand or by machinery, and it is then treated with hot water, to which acid is sometimes added, in circular vats fitted with agitators. The fibre is next dried in centrifugal wringing-machines and steam-heated drying-stoves. The fibres are next sorted again, and those suitable for yarn are passed through a species of spreading-machine, by means of which they are twisted into rope and spun into thread, the leading feature of the machines being that especial care must be taken not to place too great a strain on the yarn while it is being drawn out. For the manufacture of felt, paper, or cardboard, the short staple asbestos is converted into "half stuff" in the same kind of beating-engines as are used in paper-mills. Vegetable or animal size or water-glass is added in variable quantities, to cement the fibres, which, on account of their smoothness, have no natural felting properties; wood-pulp, silk, and other fibres are often added, and the stuff so prepared is run on to an ordinary paper-making machine and passed through two pairs of press-rollers. The damp web produced is then cut up into sheets, which are packed with metal plates into a hydraulic press, and as much of the water as possible pressed out; the sheets are then dried like ordinary hand-made paper, and again pressed to give a smooth surface.

The Paper goes on to describe the principal asbestos factories in the world, and a long list of the purposes for which the material is used. The value of Mr. Melnikoff's work is greatly enhanced by the copious marginal references he has made to the authorities which he has consulted, and to make these still more accessible, he has added, by way of appendix, a complete list of the works in which information respecting asbestos is to be found.

W. A.

On the Factories for the Dry Distillation of Wood in the Government of Orloff. By V. M. Roudneff.

(Zapisky Imperatorskavo Russkavo Technitcheskavo Obshestva [Proceedings of the Imperial Russian Technical Society] 1886, p. 35.)

After remarking that the distillation of wood is far from being carried out to an extent commensurate with the abundance of the raw material, the Author goes on to say that only the simpler products are as yet produced, namely, tar and, to a small extent, turpentine and acetic acid, although the demand for the latter product is rapidly increasing, and the quantity at present produced in Russia does not satisfy the demand.

The distillation of pine wood for the manufacture of tar and turpentine, and of birch wood for the production of acetic acid, takes place in vertical retorts 7 feet 9 inches diameter, 10 feet 6 inches high, capable of containing about 390 cubic feet of wood. The lower ends of the retorts are conical, and receive the tar which drains from the wood, while the volatile products escape by pipes from the upper ends. The retorts are arranged in pairs, and each pair is furnished with a receiver into which the vapour is first conducted, and in which a considerable quantity of the less volatile substances condense and drain away into the same receptacle into which the tar is received, while the more volatile products are condensed by tubular refrigerators. The retorts are set in cylindrical stoves, each having its own fire-grate. Distillation of the charge lasts about four days. The tar is pumped into an open copper in which it is gradually heated up to 176° Fahrenheit for the purpose of getting rid of water, it is then ready for filling into casks; 343 cubic feet of wood yield from 792 lbs. to 1,195 lbs. of tar.

The turpentine is divided into various qualities as it distils, and is then rectified in several sets of apparatus, each consisting of two wooden vessels, into the first of which is placed the impure turpentine with some water, and into the second a ley of wood ashes and lime. The contents of the first vessel are distilled by means of injected steam, and the vapours, after passing through the ley, are condensed by tubular refrigerators. In the first vessel remains a heavy liquid which is sold as carbolic acid; 343 cubic feet of wood yield about 220 lbs. of turpentine.

The preparation of acetic acid is carried on in retorts similar to those used for tar and turpentine; there are, however, no outlets from the lower ends, all the products have to pass out together from the upper tubes. The process of distillation lasts from four to five days. Acetic acid does not appear in appreciable quantities till the second day, the percentage then gradually increases and at last ceases also gradually. The tar which collects in the receiver is of poor quality, and is freed from extraneous fluids by simple settlement. The tar-water is neutralized in a separate vessel by means of lime water, after which the acetic acid is distilled off by means of injected steam. The residue is passed through settling tanks, and is then evaporated to dryness in steam-jacketed pans, the final product being an impure acetate of lime, which, after being treated with sulphuric acid, is again subjected to distillation, and the acetic acid by that means secured.

The crude acetic acid is purified by treatment with bichromate of potash and peroxide of manganese; it is again distilled, and then stored in wooden vats, from which it is drawn for delivery into barrels holding about 430 lbs. About 576 lbs. of acid at 6° Beaumé are obtained from 343 cubic feet of wood.

The paper contains a great deal of information as to details of manufacture and cost, and is illustrated by several plates.

W. A.

The Sugar-Industry in the Argentine Republic.

By Felipe Schwarz.

(Anales de la Sociedad Científica Argentina, 1886, p. 202.)

The Argentine sugar-industry being still in its infancy, with an antiquated system of manufacture, finds it difficult to compete with the more advanced methods employed in Europe and the United States, notwithstanding the high import duties on foreign-made sugar; and the object of the Author is to describe the superior machinery used in Brazil and in the island of Java, by means of which the yield from the sugar-cane is greatly increased, for unless that is introduced also into the Argentine Republic, he is of opinion that the manufacture will die out, it being already in a very depressed condition.

By the system now employed, only 3½ to 4 per cent. of sugar is recovered from the cane. The grower of the cane is also the manufacturer of the raw sugar, and he advises the separation of the two industries; by the system now in use, the cane is very imperfectly pressed, and 32 per cent. of the juice remains in the refuse and is lost, and again 25 per cent. of the sugar contained in the juice is sacrificed through ignorance of the best way to treat it. When the juice has been mixed with lime and passes to the clarifiers, this 25 per cent. would be recovered by the introduction of sulphurous gas, as is customary in Brazil and Java, which converts the carbonate of lime into insoluble sulphate of lime. The centrifugal apparatus for separating the sugar from the molasses, is also of so inferior a description that it occasions a loss of 25 per cent. in the quantity of crystallized sugar recovered, and he recommends the use of the apparatus made by Horming and Raabe, on the Schroeder-Weinrich principle, using steam instead of water in the interior of the drum, and carefully heating the mass, which much decreases the quantity of molasses, and converts nearly the whole into sugar crystals.

A still more important improvement consists in the mode of treating the cane in order to increase the yield of juice. Instead of the cane being crushed between rollers, the sugar manufacturers of Java the year before last, introduced from Germany a machine for cutting the cane into a multitude of very small round slices, not more than ⅛th or ⅛th of an inch thick. This machine resembles those used in Germany for cutting beet-root, and consists of two conical plates turning upon an axis and fitted with movable blades. In twenty-two hours 195 tons of cane were so sliced, and about the same quantity was subsequently "diffused" in twenty-four hours, in a battery consisting of ten vessels, each of which has its corresponding conducting-pipes, clarifiers, &c., the juice passing necessarily from one to the other, until the liquid was found to contain 13·61 per cent. of sugar; and the

quantity of pure sugar which was recovered by this method was 12·45 per cent. of the weight of the cane, which is more than three times as much as is obtained by the system in ordinary use at Tucuman in the Argentine Republic. The refuse contains, of course, a great deal more moisture than pressed cane; but after remaining in the sun for two or three days it dries into a very good fuel.

O. C. D. R.

Railway, Shipping, and Trade Statistics of the States of Europe.

By E. Levasseur.

(Le Génie Civil, vol. ix., p. 261, 3 woodcuts.)

After giving in two previous articles, entitled "A concise Comparison of the Productive Powers of the States of Europe,"[1] a variety of comparative statistics of the different States, illustrated by the aid of diagrams, the Author proceeds, in a final article, to give similar statistics relating to railways, shipping, and foreign commerce, both tabulated, and in the form of graphic diagrams. The total length of the railways in Europe in 1883 was 111,800 miles. Germany is at the head of the States in this respect with 22,060 miles of railway; the British Isles come second with 18,400 miles, and France next with 17,520 miles; whilst Turkey is at the bottom of the list with only 890 miles of railway. Belgium has the greatest length of railway in proportion to its area; Great Britain comes next some distance behind, followed by Germany and Switzerland; whilst Russia, though fourth in length of railway, is the worst supplied in proportion to its area, below Norway and Turkey. The railways of Great Britain carry the largest number of passengers and the greatest weight of goods per mile, and the Belgian railways have the next largest traffic per mile. Great Britain is considerably ahead of the other States of Europe both in shipping and trade; France comes next, and is followed by Germany at a short interval. Norway, Italy, and Holland possess a considerable merchant-shipping; but their trade is inferior to that of Russia.

L. V. H.

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[1] Le Génie Civil, vol. ix. pp. 218 and 245.

INDEX

TO THE

MINUTES OF PROCEEDINGS,

1886–87.—PART I.

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RETE WOR aters) PLATE I.

Fig 8.
QUEBEC QUAY-W

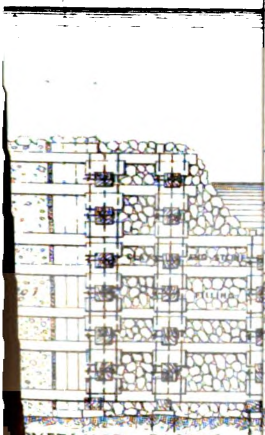


Fig. 17.
CROSS SECTION.

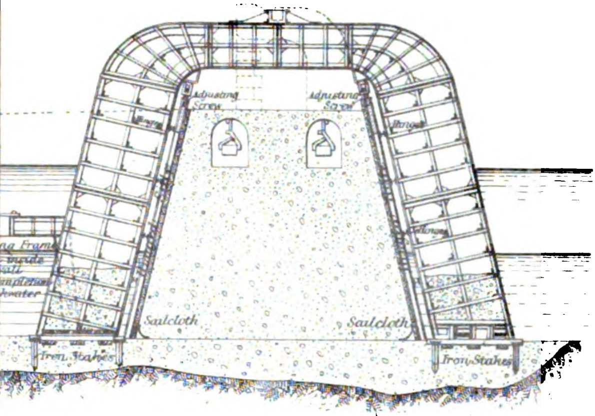
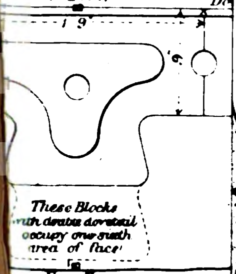


Fig 6
PLAN



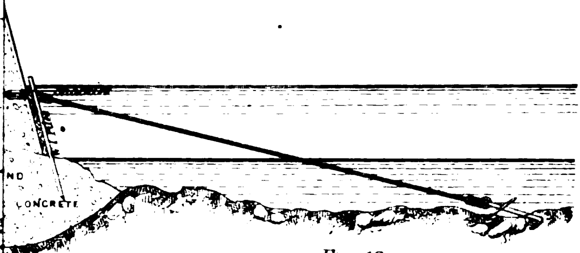


Fig. 7
SECTIONS

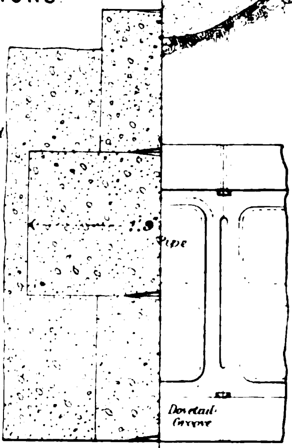
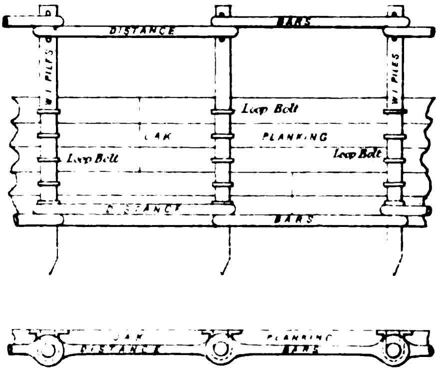


Fig. 13.
DETAILS OF FRAMING



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